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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 149.

B. T. GALLOWAY, *Chief of Bureau.*

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DISEASES OF DECIDUOUS FOREST TREES.

BY

HERMANN VON SCHRENK,

FORMERLY EXPERT IN CHARGE OF THE MISSISSIPPI VALLEY LABORATORY OF THE BUREAU OF PLANT INDUSTRY,

AND

PERLEY SPAULDING,

PATHOLOGIST, INVESTIGATIONS IN FOREST PATHOLOGY.

ISSUED JUNE 30, 1909.

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1909.

NATURAL RESOURCES

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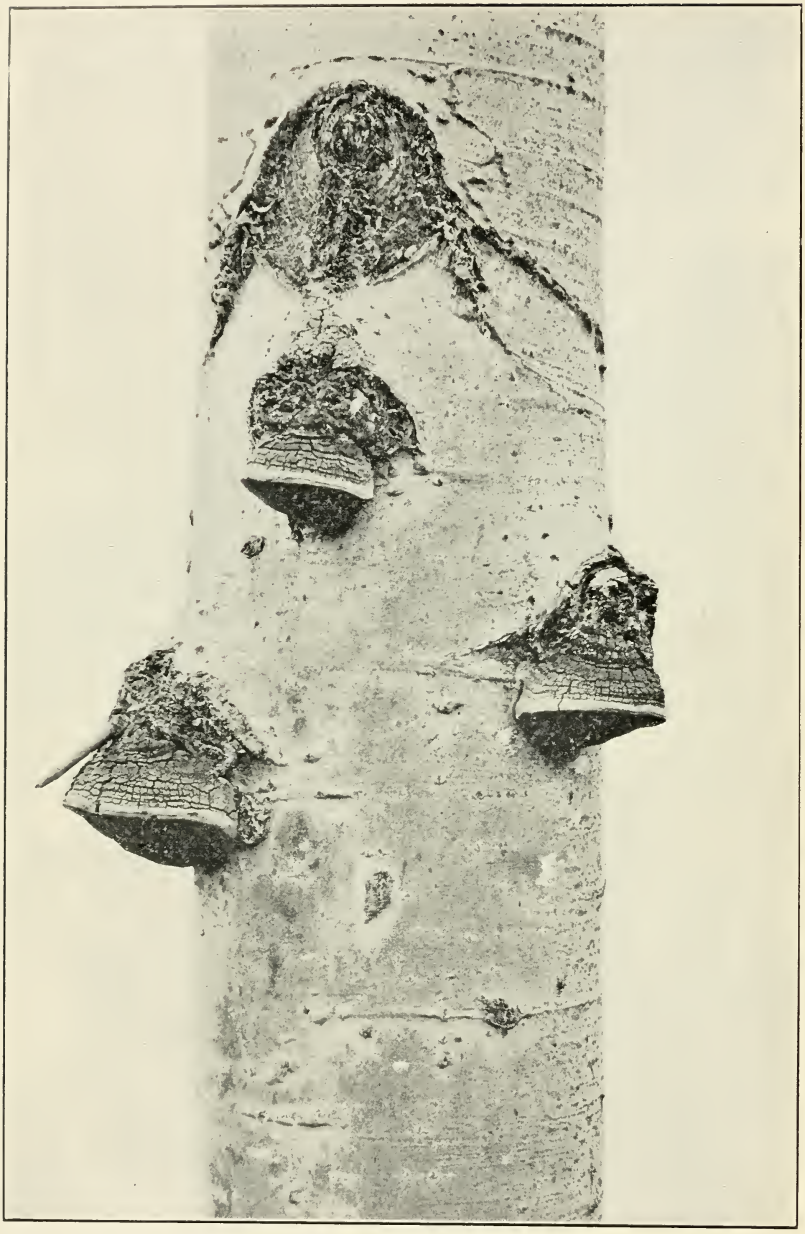

A LIVING ASPEN TREE WITH SEVERAL SPOROPHORES OF FOMES IGNIARIUS.

U. S. DEPARTMENT OF AGRICULTURE.

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B. T. GALLOWAY, *Chief of Bureau*

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Carl Hartley, *Scientific Assistant.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 12, 1909.

Sir: I have the honor to transmit herewith a paper entitled "Diseases of Deciduous Forest Trees," by Hermann von Schrenk, formerly Expert in Charge of the Mississippi Valley Laboratory of the Bureau of Plant Industry, and Perley Spaulding, Pathologist, Investigations in Forest Pathology.

The paper embodies the results of several years of investigation and gives a general account of the principal diseases of our hardwood forest trees. I recommend that it be published as Bulletin No. 149 of the series of this Bureau.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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DISEASES OF DECIDUOUS FOREST TREES.

INTRODUCTION.

Deciduous forest trees are affected with a large number of different forms of disease, some of which are daily assuming more and more importance. While it has been well known for many years that there are such diseases which are prevalent among broadleaf forest trees, very little has been accomplished up to the present time in the study of their occurrence, the amount of destruction which they cause, and the practical methods of prevention. In dealing with timber tracts, whether they be wood lots or larger areas, it is becoming of increasing importance to take cognizance of those factors which cause depreciation in value of the timber produced, either by decreasing the value of the wood cut or by retarding or preventing the growth of the trees themselves. The various types of disease affect both young and old trees, and from the time the seedling starts to develop until it has reached maturity it is liable to attack by one or more destructive diseases.

In the present bulletin the results of a number of years' investigation of some of the more important diseases of deciduous trees are discussed. No attempt is made to include in this paper all of these diseases. Many are local in their distribution and are as yet of minor importance from a practical standpoint. Many of them affect shade and ornamental trees rather than forest trees. All such are left for subsequent discussion.

For the sake of convenience the diseases of trees may be divided into several groups. Basing the classification on the causes of disease, they may be divided into those caused by unfavorable environmental conditions, including smoke or injurious gases, extreme cold, lightning, excessive water supply, etc., and those caused by living organisms—animals, insects, flowering plants, fungi, and bacteria. Those fungi which cause disease may again be classified into such as grow in the living parts of the tree, including the leaves, the younger branches, the newly formed wood and bark, and the living portion of the root system, and those which grow on the dead or dying parts of the tree, including the heartwood of the trunk, branches, and roots.

ENVIRONMENTAL DISEASES.

In a bulletin of this kind it is impossible to more than refer to certain general types of diseases caused by unfavorable environmental conditions. Of such conditions the principal ones affecting American broadleaf trees are undoubtedly smoke and injurious gases.

SMOKE AND SULPHUR GASES.

In many parts of the United States (7, 37, 71, 109[a]) extensive areas of deciduous forest lands have been severely injured by the action of smoke or sulphur gases emanating from paper-pulp mills, copper smelters, coke ovens, and blast furnaces. The effects of the sulphur gases first show themselves in deciduous trees either by a discoloration of the young leaves, which ultimately turn mottled yellow and brown and finally die, or by a gradual shriveling and drying of the leaves. A general reduction in the rate of growth likewise takes place, both in the length of the twigs and in the amount of wood formed by the trunk.

In both broadleaf trees and conifers the first effect of smoke or gas injury is usually seen in the tops. This refers especially to trees standing together in a forest or in groups. Single trees may first be affected either in that manner or throughout the crown generally. The leaves in the top gradually become smaller and die, while those near the base may be perfectly healthy. The smaller twigs in the top die next, then larger branches, and with long-continued exposure to injurious gases the tree slowly dies downward until it is killed.

The extent to which trees become diseased as a result of the action of sulphur gases varies materially with the species and the distance from sulphur-gas formation. Buckhout (7) finds twice as much sulphuric acid in the leaves of white oaks grown three-fourths of a mile from a large range of coke ovens as occurred in similar leaves taken from the vicinity of the Pennsylvania State College.

The results of an extended investigation on the effect of smelter fumes on vegetation were recently published by Haywood (37), who confirms the extensive experience of European investigators (36, 112) as to the killing effect on vegetation of very small quantities of sulphur dioxid in the air. Haywood found that in the vicinity of the copper smelters where his investigations were carried on the injury showed itself by the increased sulphur trioxid content of the foliage. He found that the vegetation around the smelter for at least 3½ miles north, 9 miles south, 2½ miles east, and from 5 to 6 miles west had been greatly injured. He suggests that the gases from the

[a] The serial numbers used in this paper refer to the bibliography which will be found on pages 69 to 73.

smelter can be condensed so as to form sulphuric acid, a readily salable product.

Different species of trees show a marked difference in susceptibility to the action of sulphur gases. As a rule, conifers are killed much more readily than deciduous trees. This may be explained by the facts that gases are injurious only to the leaves of trees and that the leaves of coniferous trees are exposed to the gases for several years, while the leaves of broadleaf trees are renewed from year to year. In Germany, where many detailed examinations have been made during a number of years, Haselhoff and Lindau (36) state that the oak is the most resistant tree, followed closely by the different species of maple and ash. The elm, alder, poplar, and linden are more susceptible, and the birch and beech are most susceptible. Haywood states that 3½ miles north of a smelter large numbers of trees, especially pines, were dead.

A series of investigations has been conducted for several years by the senior writer in another region where an extensive mixed forest has been severely injured by sulphur gases emanating from large copper smelters. The forest consists largely of oaks and pines growing on an extremely poor and sterile soil, and the general development of the forest, even before the action of the sulphur gases, was very poor. The different species of forest trees showed a marked difference in susceptibility. The order of susceptibility, beginning with the trees most easily killed, is as follows:

White pine (*Pinus strobus* L.).
Hemlock (*Tsuga* sp.).
Scrub pine (*Pinus virginiana* Mill.).
Pitch pine (*Pinus rigida* Mill.).
Chestnut oak (*Quercus prinus* L.).
Hickory (*Hicoria* sp.).
Black-jack (*Quercus marilandica* Muench.).
White oak (*Quercus alba* L.).
Post oak (*Quercus minor* (Marsh.) Sargent).
Chestnut (*Castanea dentata* (Marsh.) Borkh.).
Spanish oak (*Quercus digitata* (Marsh.) Sudworth).
Scarlet oak (*Quercus coccinea* Muench.).
Tulip poplar (*Liriodendron tulipifera* L.).
Maple (*Acer* sp.).
Black gum (*Nyssa sylvatica* Marsh.).

This list pertains to trees of pole size. During the sapling stage a somewhat different series can be established. The saplings of post oak and white oak are less easily affected than those of Spanish oak and scarlet oak. The degree of discoloration of the leaves varies, and this should be considered an important factor in diagnosing smoke or gas injury. The following shows the susceptibility to discoloration in a number of different species.

Very easily discolored: Black oak (*Quercus* sp.), hickory (*Hicoria* sp.), scarlet oak (*Quercus coccinea* Muench.), chestnut (*Castanea dentata* (Marsh.) Borkh.), and Spanish oak (*Quercus digitata* (Marsh.) Sudworth).

Partially resistant to discoloration: Tulip poplar (*Liriodendron tulipifera* L.), white oak (*Quercus alba* L.), chestnut oak (*Q. prinus* L.), and post oak (*Q. minor* (Marsh.) Sargent).

Quite resistant to discoloration: Black gum (*Nyssa sylvatica* Marsh.), white pine (*Pinus strobus* L.), maple (*Acer* sp.), pitch pine (*Pinus rigida* Mill.), and hemlock (*Tsuga* sp.).

A great variation in susceptibility to gas injury has been noted by the senior writer in different regions, largely because the general growth conditions have a direct relation to the question of smoke and gas resistance. Trees growing in good soil, not too close together, so that they grow vigorously, are more resistant than those grown on poorer soils or crowded together. Whether smoke or gas has any direct influence on the soil, thereby causing disease in the roots, has not yet been definitely determined. Haselhoff and Lindau (36) conclude that the smoke or gas has no influence whatever on the soil, while Wieler (112) cites a striking instance showing that soil from a smoky district is very injurious to healthy trees planted in it. After three years' growth in soil from a gas district, 100 per cent of ash, 92 per cent of maple, 72 per cent of beech, 8 per cent of spruce, and no oak trees were dead.

The greatest distance at which the sulphur fumes injured trees was about 3 miles, toward the north and northwest.

The most extreme gas injuries usually occur close to the source of gas production, and injury diminishes rapidly as the distance from this point increases. The injury is furthermore greatest in the direction in which the prevailing winds blow. It is usually most extreme where the source of gas production is in confined valleys or basins (37).

Preventive measures with reference to gas injury can often be carried out with much success. These consist in the construction of tall smokestacks at the manufacturing plant where the injurious gases originate, so as to carry them into the higher strata of the air. The same end may be obtained by the erection of the manufacturing plant at the most elevated point in any given region. A second method which has been used with more or less success in Europe consists in bringing about the condensation of the gases by passing the smoke from furnaces or kilns through water.

UNFAVORABLE SOIL CONDITIONS.

Under unfavorable soil conditions a large number of disease-causing factors are usually grouped, most of which are but imperfectly recognized so far as their specific action is concerned. Among these may be mentioned the absence of a sufficient amount of oxygen in the soil, the absence of necessary food substances, the absence of

water or its presence in excess, the absence of humus or its presence in excess, and a generally unfavorable physical make-up of the soil. For a general discussion of this question see Galloway and Woods (27).

Different species of deciduous trees are affected in different ways by any or all of these conditions. Certain species thrive on dense, clayey soil which has but little aeration and which is generally comparatively free from vegetable matter, while others present a starved appearance on such soil, which is usually recognized in the tree by a dying back of the topmost branches, giving rise to what is usually known as a "stag-headed" condition. This same appearance is brought about in some cases by an excessive amount of ground water. The beech (*Fagus atropunicea* (Marsh.) Sudworth), the tulip poplar (*Liriodendron tulipifera* L.), and the true white oak (*Quercus alba* L.) are trees which are particularly sensitive to excessive water supply in the soil. On the other hand, the red gum (*Liquidambar styraciflua* L.), overcup oak (*Quercus lyrata* Walt.), and water oak (*Q. aquatica* Walt.) are more tolerant in this respect.

Most forest trees demand light and comparatively porous soils with a considerable percentage of humus material, so as to make possible a perfect development of the mycorrhizal fungus and of other species of soil fungi and bacteria. Although we do not fully understand their exact relation to the roots of forest trees, nevertheless these organisms appear to exercise a considerable and usually beneficial influence upon their general development. A reduced rate of growth, pale green, yellowish, or etiolated leaves, and the development of large numbers of short, sucker-like branches may one or all usually be taken to indicate a weakened or diseased condition due to soil troubles. Insufficient room for root development constitutes another very important factor leading to a weakened or diseased condition.

In many hilly or mountainous regions of this country the shallow soil gives rise to a dwarfed and weakened forest growth. No more striking picture of the result of a shallow soil as compared with a deep, rich soil can be found than in the difference evident in the general healthiness of the trees in the Ozark Mountains when compared with those of the western slope of the Appalachian Mountains. Both of these regions receive a heavy annual rainfall, but in the Ozarks the hardpan often comes to within 2 feet of the top of the ground, and as a result a stunted and diseased forest growth develops, while in the Appalachians a very deep soil, rich in humus, permits an extensive and vigorous root development, resulting in healthy, vigorous trees.

EXTREME COLD.

Extreme cold may sometimes result in a diseased condition of trees, either by killing roots or young shoots outright (25, 63, 107, 110, 111), or by causing injuries, such as frost cracks, in the trunks or

branches, which make possible the entrance of disease-producing organisms at a later date. The winter of 1904–5 was characterized by extreme cold and resulted in considerable destruction to forest trees all over the country. Hail, sleet, and snow produce injuries to forest trees which are often extreme; their chief importance lies in the fact that they produce injuries leading to diseases caused by fungi or insects acting upon such trees at a subsequent date.

INJURIES CAUSED BY ANIMALS, WIND, ETC.

The injuries caused by the biting or chewing of animals may be classed in the same category as the injuries referred to under snow and ice, and injuries produced by windstorms may also be placed in the same class. It is very rare to find a large forest tree which is seriously affected because of such injuries, except in the case of violent windstorms. The chief importance of such wounds lies in the fact that they open up pathways for destructive forms of insects or fungi, which are referred to more in detail hereafter. Of these factors, the action of the wind in breaking off branches from more or less mature trees must be considered as the most important.

DISEASES CAUSED BY MISCELLANEOUS PARASITIC AND SAPROPHYTIC ORGANISMS.

The diseases caused by parasitic or saprophytic organisms may for convenience be divided into three groups: Those caused by insects, those caused by parasitic higher plants, and those caused by fungi and bacteria.

DISEASES CAUSED BY INSECTS.

The disturbances in the activities of the living parts of trees caused by insects are not usually classed in any discussion on diseases of plants, although the changes which they produce undoubtedly should be considered rather from the standpoint of the plant than from that of the insect causing them. No special reference will be made in this discussion to any of the diseases of broadleaf trees caused by insects. These have been described in the publications of the Bureau of Entomology of the United States Department of Agriculture by Dr. A. D. Hopkins (42, 43), and a number of them by Dr. E. P. Felt (18 to 21) and others (22, 49, 66, 67, 87) are mentioned in the bibliography.

DISEASES CAUSED BY PARASITIC HIGHER PLANTS.

Many species of deciduous trees are attacked by the common mistletoe (*Phoradendron flavescens* (Pursh) Nutt.). This parasite is very prevalent from the vicinity of the Ohio River southward, and west-

ward to southern California. Throughout southern Ohio, Indiana, Illinois, and Missouri it is found chiefly on the black gum (*Nyssa sylvatica* Marsh.). In the Southern States it is found on almost all species of deciduous forest trees, including the sycamore (*Platanus occidentalis* L.), elm (*Ulmus americana* L.), oaks (*Quercus* sp.), red gum (*Liquidambar styraciflua* L.), ashes (*Fraxinus* sp.), cottonwood (*Populus deltoides* Marsh.), and many others of the smaller shrubby species of trees, like the mesquite (*Prosopis juliflora* (Swartz) DC.).

Where it is present in any large quantity, the mistletoe is regarded as a serious enemy of the trees upon which it grows. In the more or less virgin forest tracts of the Mississippi Valley, extending from southern Missouri into Arkansas and northeastern Louisiana, many tracts are found which are so badly infested as to seriously interfere with the annual rate of wood accretion. In the extreme Southern States vigorous efforts are being made to prevent the attack of the mistletoe, which has become a serious enemy to forest and shade trees in southern Louisiana and Texas. The parasite is distributed from tree to tree chiefly by birds, and when it has once obtained a foothold in any given region, practically every tree in that locality is affected by it. The parasite is a perennial and gradually absorbs the food materials from the branch upon which it is situated, and not only kills off that part of the branch toward the outside of the tree from its point of attachment, but also causes the formation of large swellings, or tumors, which are most characteristic in the black gum. Figure 1 shows the extent to which the oak may be attacked by this parasite.

FIG. 1.—Oak trees with mistletoe on the branches. Some trees become literally covered with this pest.

There are also a considerable number of smaller mistletoes belonging to the genus Arceuthobium which are widely distributed throughout the country. Of these there are two which may be especially mentioned: *Arceuthobium cryptopoda* Engelmann and *A. pusillum* Peck. The former is known to occur in various sections of the Rocky Mountains and is injurious to a number of different coniferous hosts; the latter seems to be an eastern form, limited more or less closely to the Appalachian Mountains, and is definitely known to occur from the Canadian border to southeastern Pennsylvania. The different species of Arceuthobium resemble each other very much in their habits of growth, their manner of seed dispersal, and their effect upon their hosts, so that we may take the best-known form, *Arceuthobium pusillum*, as a type of this group (77).

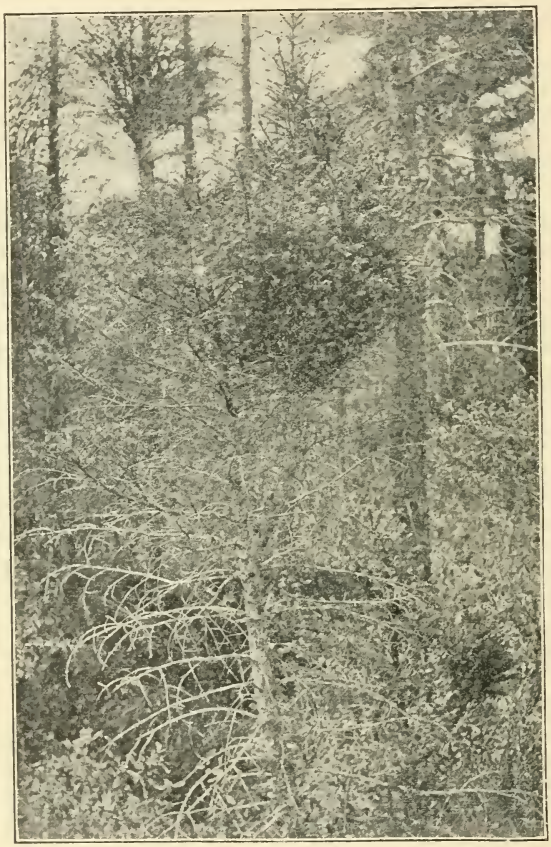

FIG. 2.—A black spruce tree with a large witches' broom caused by dwarf mistletoe.

The seeds are coated with a mucilaginous substance. Upon ripening they are projected for several feet from the seed capsules, and alighting upon an adjacent branch or twig they stick tightly to the bark and there germinate. They may also be sometimes carried by birds.

The young plant pierces with its holdfast the bark of the twig upon which it is seated and establishes communication with the living portions of the twig. It is thus enabled to feed upon the sap of its host, and in this way a considerable amount of food material is diverted from the outer end of the affected branch to the parasite. About the point of infection a number of branchlets develop, and in the course of a few years there is formed a compact, bushy mass of twigs which

is known as a "witches' broom." (See fig. 2.) During the course of the development of these witches' brooms the sap becomes diverted more and more completely from the outer end of the affected branch to the broom, and finally that part of the branch located beyond the base of the parasite dies. These witches' brooms vary much in size, being from only a few inches in diameter to as much as several feet in diameter and in height. The distribution of the seeds is such that a tree once infected is almost sure to become more affected as time goes on, so that in extreme cases there seems to be little doubt that large trees may be entirely killed by the effects of this plant. The senior writer (77) has referred to the apparent destructive action of this plant. It is evident that the most practical method of eradicating this parasite is by cutting all of the affected trees and burning the infected parts.

FIG. 3.—Spanish moss on a large oak tree. Note that the branches bearing the moss are dead.

It is believed that a number of epiphytic plants sometimes bring about a diseased condition of deciduous trees by smothering the younger leaves and branches. (See fig. 3.) The southern moss (*Tillandsia usneoides* L.) is believed by many to cause the death of leaves and branches of the live oak (*Quercus virginiana* Mill.), red gum (*Liquidambar styraciflua* L.), and other deciduous trees. The dense masses of this plant frequently cover the growing parts of the tree and deprive them of air and light. Another species, *Tillandsia recurvata* L., has recently been reported as killing the live oak (*Quercus virginiana* Mill.) and pecan (*Hicoria pecan* (Marsh.) Britton) in southern Texas. In the Northern States mosses and lichens frequently grow in such profusion that injurious results follow. This is par-

ticularly true of *Usnea barbata* (L.) Fr. and *Ramalina reticulata* (Noehd.) Krempelh. (68). Trelease (100) reports similar effects due to tree mosses. Dense masses of lichens growing on the bark of trees are described as injurious by Waugh (105, 106), Waite (104), and others (44). While these epiphytes may be directly responsible for injuries, and even death, it should be stated that the evidence in favor of such an assumption is not very conclusive. It may be that these plants grow on trees already weakened by other factors. No definite proof has yet been brought forward which would indicate that leaves and branches are killed because of the growth of these plants on the branches.

DISEASES CAUSED BY MISCELLANEOUS FUNGI.

As indicated in the introduction, the fungi which cause disease may be roughly classified into two groups: Those which grow on the living parts of trees and those which grow on the dead parts. Of the forms growing on living parts, one may distinguish in a general way between such as attack growing leaves and those which attack the living branches or wood. Leaf fungi usually attack leaves in spots and produce local disturbances evident as discolored, shriveled spots, which in time dry and break away entirely, leaving holes. In other cases they may bring about malformations of the leaves, causing them to become swollen or much curled and twisted. In many instances the leaves attacked by various species of fungi are killed and prematurely shed. While it is not practicable to include a list of all the forms of fungi which cause leaf diseases of deciduous trees, some of the more important may be mentioned.

MILDEWS.

Among those fungi which attack the surface of the leaf are the various mildews caused by the fungi of the family Erysipheæ. These fungi are found on many species of deciduous forest trees and are most common on the red oak (*Quercus rubra* L.), elm (*Ulmus americana* L.), silver maple (*Acer saccharinum* L.), sycamore (*Platanus occidentalis* L.), and willow (*Salix* sp.). They usually appear during the latter part of the summer, and because of their late appearance do slight harm, except where they attack young forest trees and nursery stock. The small, round, black fruiting bodies are dotted here and there over the diseased surface of the leaf (102).

Finely powdered sulphur dusted lightly over the leaves and young twigs will hold these diseases in check. This is very useful where small trees or nursery stock are to be treated. The standard Bordeaux mixture as well as any other of the efficient fungicides will control this trouble, but sulphur is preferable unless treatment is wished for other fungous troubles also.

TAR-SPOT.

The tar-spot disease of the maple, caused by *Rhytisma acerinum* (P.) Fr. (34, 35, 102), shows as black, irregularly shaped spots on the leaves of different species of maples in the latter part of the summer. These black, blister-like spots sometimes occur very thickly scattered over the leaves, and in cases where the attack is severe the foliage is shed prematurely and the trees weakened thereby. The fungus causing the disease develops beneath the epidermis of the leaf during the summer and forms a black mass of mycelium. After the leaf falls to the ground the fungus continues its development and the following spring produces immense numbers of spores, which it is supposed are blown by the wind on to the newly formed leaves of the second summer.

A number of other species of Rhytisma infest other trees than the maples. In some seasons considerable damage is done, especially to nursery stock of various ages, in which case the appearance is very badly marred, both by the premature falling of the leaves and by the black spots upon them while still clinging to the tree. Methods of prevention consist in carefully raking the leaves together and burning them in the fall, thus preventing the fungus from attaining maturity the succeeding spring. This treatment alone if carefully done should prevent serious inroads from this disease.

RUSTS.

Deciduous forest trees are affected only to a limited degree by rust fungi. Now and then one finds a leaf-rust (*Puccinia fraxinata* (Lk.) Arthur) both on the white ash (*Fraxinus americana* L.) and green ash (*F. lanceolata* Borkh.), the telial stage of which occurs on *Spartina cynosuroides* (1). A similar disease is caused on the poplar, willow, and birch by other closely related rusts, namely: *Melampsora populina* (Jacq.) Wint. on poplar (*Populus deltoides* Marsh.) (24), *M. betulina* (Pers.) Wint. on birch, and *M. saliciscaprae* (Pers.) Wint. on willow. These species of rust appear on the leaves in early summer as very minute, bright yellow spots, which gradually turn darker as the season advances, and in the autumn are almost black. The dark-colored spores, which are formed last, are the mature winter spores of the fungus which enable it to live over the winter. The amount of damage done by these rusts is usually insignificant on large trees, but in some seasons when the weather conditions are favorable trees may be entirely defoliated. The most extensive damage done by them is in young plantations, this being especially true of the willow leaf-rust, which has occasioned

considerable damage in osier willow plantations (93). Where the disease is destructive the affected leaves which have fallen to the ground should be raked together and burned.

SYCAMORE LEAF-BLIGHT.

The different species of sycamore, and more especially the common sycamore (*Platanus occidentalis* L.), are very generally affected throughout this country and Europe by a leaf and twig blight caused by the fungus *Gloeosporium nervisequum* Sacc., which in its perfect form is known as *Gnomonia veneta* (Sacc. & Speg.) Kleb. (45). This fungus attacks the young leaves at about the time they reach full growth. The attack usually takes place at or near a large vein of the leaf, resulting in the stoppage of the water supply of considerable areas of the leaf, thus leading to the death of these areas. The deadened portions are usually located, as above indicated, along the main veins of the leaf. Sometimes the attack is made on the petiole of the leaf or on the young twig, causing the death of an entire leaf or bunch of leaves. In severe attacks the leaves are dropped prematurely, and if the attacks are continued with intensity for several years the trees become seriously weakened, and may even die outright.

This trouble is exceedingly common of late years and occurs so universally upon the sycamore that the damage is becoming noticeable, especially upon the park and street trees. Raking together the fallen leaves and burning them, pruning out dead twigs and branches, and spraying with Bordeaux mixture where expense is not a consideration should completely control this trouble (24, 35, 102).

LEAF-SPOTS.

A large number of minute forms of the imperfect fungi belonging to the genera Cercospora, Phyllosticta, Ramularia, and Septoria attack the foliage of many of the deciduous trees and cause the so-called "leaf-spots." Leaves affected with these diseases usually exhibit more or less numerous deadened areas of small size. Early in the season these spots are apparently sterile, but later a close examination will reveal a number of tiny black specks located near the middle of the area. These are the fruiting bodies of the fungus, in which are produced the spores for the production of still other colonies. The maple leaf-spot fungus (*Phyllosticta acericola* Cook & Ellis) (24, 102) may be taken as a type of this class of diseases. It is quite common upon the various species of maple, and in severe attacks where a large proportion of the leaf surface is affected the leaves drop prematurely. As a general thing, however, these dis-

eases occur locally and do not affect the leaves so seriously as to cause them to fall before they should naturally. Collecting and burning the fallen leaves and spraying where practicable will control this trouble.

LEAF-BLISTER FUNGI.

The leaf-blister fungi, belonging to the Exoasceæ, attack the leaves of a number of the deciduous trees and deform them. The species which is best known in this country is probably *Taphrina cærulescens* (Mont. & Desm.) Tul., which occurs upon the foliage of a number of different species of oak in various parts of the country (114). This disease attacks the newly formed leaves and causes an abnormal growth, so that the leaf looks as if blistered over the affected areas. The development of the fungus is quite rapid, and in extreme cases defoliation may result from its attacks. The cumulative effect of this disease where it occurs for several years upon the same trees may result in the death of the affected trees. Burning the fallen leaves and spraying where practicable will hold this disease in check.

NECTRIA CINNABARINA.

Nectria cinnabarina (Tode) Fr. has sometimes been considered a parasite (23, 27, 52, 69, 102), but should really be considered a hemiparasite. Its spores obtain entrance into branch wounds caused by hail, rodents, or birds, and the resulting mycelium grows through the partially weakened wood and ultimately produces small red clusters of fruiting bodies. The stimulus exerted upon some of the living portions of the cambium layer by the presence of the fungus mycelium frequently accelerates the callus production at the edge of the wood. The callus of the first year is then invaded by the fungous mycelium and killed, and a second layer of callus starts to develop. This may happen for a number of years, until a large area of dead wood having the appearance of a virulent canker is formed on the branch or trunk. Where these cankers grow to be of any size they ultimately result in the death of the branch, or where they occur on a young tree, in the death of the tree itself.

There is a large group of the fungi belonging to the Pyrenomycetes, a number of which attack the living tissues of the bark and the wood of trees weakened by one cause or another. These fungi will usually not attack a vigorous tree, but after a tree has been weakened, either by unfavorable soil or atmospheric conditions or by the attack of some animal, fungus, or insect, they gain a foothold and may produce more or less serious forms of disease. They likewise obtain entrance through wounds into tissues which may properly be called living tissues. The members of the genus Nummularia are

good examples of this type of fungus. Their black fruiting bodies are usually found on the dead or dying wood of the branches or trunks of trees, particularly of the oaks and beeches.

CHESTNUT BARK DISEASE.

The chestnut (*Castanea dentata* (Marsh.) Borkh.) has been almost completely exterminated over extensive areas adjacent to the city of New York by a fungus known as *Valsonectria parasitica* (Murrill) Rehm. (54, 55, 56, 60, 61, 62, 70). It causes patches of the bark to die by attacking the cambium and other soft tissues of the bark, and extends in all directions until the branch or trunk is girdled. This leads to the death of those parts above the girdling, and in this way if the main trunk is attacked the entire tree may be killed. The disease attacks the bark on the twigs, branches, and trunk without respect to its thickness. How the fungus gains entrance is uncertain, but inoculation experiments (60, 61) seem to show that it is able to enter only through injuries to the bark. The affected bark has a blackened appearance, is somewhat shrunken, and after a time is apt to be thickly covered with projecting brown or orange or greenish yellow colored bodies, which are about one-sixteenth inch in diameter at the base, often long and twisted or curled, and taper to a slender tip. These are the fruiting bodies of the fungus and are very characteristic of this disease when the weather is moist enough for their formation.

The disease has already spread south to Bedford County, Va., west to Lancaster County and Northumberland County, Pa., and north to Massachusetts. The Japanese chestnut (*Castanea crenata* Sieb. & Zucc.) is in general resistant, although single trees of this species have taken the disease. Immunity tests of all known varieties of chestnuts are now in progress by this Department (55, 56) No adequate preventive measures seem to be known at present, so that this disease is an especially threatening one in the Eastern States.

A similar disease has been noted by the writers upon the Spanish oak (*Quercus digitata* (Marsh.) Sudworth) in the Appalachians, especially in Virginia and western North Carolina. This disease is manifested in the drooping of the leaves and their ultimate drying up, caused by a stoppage of the water supply in the branches by an apparently undescribed species of Cenangium.

ROOT-ROTS.

Of the fungi which attack the living roots, two deserve particular notice. Diseases of the root system of broadleaf trees are usually classed together under the term "root-rots." By this is meant a disease which shows in the tree tops by a gradual dying of the branches

and generally by a sudden wilting of the leaves during the latter part of the spring.

Root diseases may be caused by unfavorable soil conditions as well as by fungi, but it has been the experience of the writers that there is a decided difference in the behavior of diseased trees where soil conditions are responsible, as compared with diseased trees affected with some fungous trouble. In the former case the tree dies gradually and the stag-headed condition, together with a gradual decrease in the annual rate of growth, is very pronounced. Where fungi are responsible for root-rot the trees ordinarily show slight indications of the disease in the trunk and crown until it has reached an advanced stage. They then usually send out an unusually large number of leaves and exhibit a strong tendency to overdevelopment of the flowers and fruits.

Two fungi have been found in the United States which have been definitely connected with one or the other type of root-rot. It is probable that there are several others. While it is easy to find a fungous mycelium in diseased roots, it is a comparatively difficult matter to determine with any degree of certainty that the fruiting bodies found near diseased trees bear any direct relation to the mycelium which occurs in the diseased root system.

Only brief reference can be made here to the manner of growth and attack of the two root-rotting fungi. The more important of these is the ordinary "Hallimasch" of the Germans, or the so-called honey mushroom (*Armillaria mellea* (Vahl.) Quelet) (27, 32, 34, 35, 102), a form of which may be what has been named *Clitocybe parasitica* by Wilcox (113). The fruiting bodies of this fungus usually occur in large numbers around the base of the trunk of a diseased tree. They are also found frequently in dense masses on and around dead tree stumps. The fruiting bodies are honey colored and the tops have a more or less viscid appearance, speckled with white. The stems are somewhat swollen at the base, and a short distance below the pileus they have a distinct ring, or annulus. The gills are white, and from them large quantities of white spores are shed, which frequently cover the ground around the fruiting bodies, like a mealy white powder.

The most characteristic parts of the honey mushroom are the so-called rhizomorphs, known popularly as "shoe strings." These consist of hard, black strands which occur singly or in large numbers, frequently much interlaced and branched, extending in all directions through the ground and along the roots or stumps of affected trees. Where they grow under the bark and in the cambium layer, they become much flattened. The fruiting bodies of the honey mushroom are found to develop at the ends of these rhizomorph strands.

The fungus usually gains entrance through some wound in the root system, although it has been maintained that it can penetrate the bark of uninjured trees. The young mycelium grows into the cambium layer, attacks the living cells, and finally completely encircles the base of the trunk of an affected tree. As the fungus continues to develop, masses of the mycelium form rhizomorph strands. The ultimate effect of the presence of the fungus is to kill the living layers of the tree near the ground line, causing a drying of the top and the ultimate death of the entire tree.

The fungus continues to live in the dead root system and in the base of the trunk of the tree for a number of years, and the rhizomorphs are able to continue their growth from root to root for some years after the trees have died. It is this faculty which makes this fungus an exceptionally dangerous one, because it is thereby enabled to spread from tree to tree through the soil with great readiness. The writers' observations show that the dead pieces of roots left in newly cleared forest land are sources of infection for the roots of fruit trees when planted on such land a few years later.

The second fungus, which affects trees very much as does the honey mushroom, is a root fungus (*Thelephora galactina* Fr.) (82) which has so far been found only on various species of oak, particularly the black oak. It has been found to occur commonly in various parts of the Ozark Mountains in southwestern Missouri, western Arkansas, and eastern Indian Territory. The long white strands of this fungus penetrate the bark of oak trees until they reach the living tissues. The fungus generally attacks the younger trees, and when the soil conditions are favorable for its development, considerable areas of oak forest may be killed as a result of its activity. It is one of those forms which cross from oaks to fruit trees when planted on newly cleared land.

SLIME-FLUX DISEASES.

A class of diseases known as slime-flux diseases should be referred to here, because they are frequently found on many of the deciduous trees. The slime-flux diseases are common in this country on the yellow birch (*Betula lutea* Michx. f.), elm (*Ulmus americana* L.), dogwood (*Cornus florida* L.), apple (*Pyrus malus* L.), and maples (*Acer* spp.). They are characterized by the appearance of various colored, slimy masses with a decidedly acid odor, which start at or near wounds caused by different agencies (23, 102). They make their appearance usually early in the spring when the sap, containing more or less sugar, flows from the wounds mentioned. In this sap a number of forms of algæ, bacteria, and fungi, usually associated with certain low animal forms, flourish extensively. The fermentive processes set up by one or all of these forms kill the underlying bark and cam-

bium, and where they are allowed to develop to any extent their destructive action may extend completely around a tree, resulting in the death of branches, and sometimes of the entire trunk. The slime-flux diseases can hardly be considered of great practical importance and only become so where valuable shade or park trees are affected. As a preventive measure, the precautions to be taken for wounds, referred to farther on, are applicable.

DISEASES CAUSED BY WOUND FUNGI.

WHITE HEART-ROT CAUSED BY FOMES IGNIARIUS.

The principal diseases of deciduous forest trees are caused by a group of fungi which grow in the heartwood of the trees. The chief interest which attaches to the maintenance of wood lots or forest tracts comes from the fact that such tracts are maintained for the wood which they produce. Anything, therefore, which either reduces the rate of wood production or actually destroys the wood formed is of particular interest.

The fungi which are responsible for the decay and destruction of the heartwood of various broadleaf trees are quite numerous. They are more or less alike, however, as to their manner of entrance into the tree, their subsequent development, the production of their fruiting bodies, and the manner of prevention. In the following, one of the commonest of these fungi, the so-called "false-tinder fungus" (*Fomes igniarius* (L.) Gillet), is taken as a type, and such specific differences as apply to the other forms are given in the special chapters in the latter part of this bulletin which are devoted to the more important of these wood-rotting fungi.

NATURE OF DISEASE CAUSED BY FOMES IGNIARIUS.

The disease of deciduous trees caused by the false-tinder fungus (*Fomes igniarius*) may be called the "white heart-rot." It is usually confined to the heartwood of the tree, including the trunk and larger branches, but it may also affect the sapwood. As a result of the action of the false-tinder fungus the heartwood is changed into a whitish, soft substance, which differs little in the different species of hosts.

A tree attacked by the fungus shows no particular change in its general external appearance during the early stages of the disease; in fact, it is practically impossible to recognize a diseased tree until the fruiting bodies of the fungus form on the outside of the trunk. During the later stages of the disease affected trees can be recognized by the presence of the fruiting bodies of the fungus, of which there may be from one to a dozen on a single tree, at or near wounds, branch

stubs, or knot holes. When these fruiting bodies appear it may be taken for granted that the disease has progressed within the trunk in both directions for 2 or 3 feet from the point of infection.

The disease may affect trees at any time. In its final stages it brings about a complete destruction of the heartwood of the tree, so that it becomes weakened and liable to be broken off by windstorms, thus terminating the existence of the affected tree. Diseased trees may sometimes be recognized by the sound emitted when the trunk is pounded on the outside. While healthy trees give a vibrant sound, trees in the later stages of the disease give a more or less deadened sound. This is especially true where, owing to the destruction of the decayed wood by insects, holes have been formed. As a general rule, however, the only safe way to recognize a diseased tree is by the presence of the punks or fruiting bodies on the outside of the trunk.

When cut in two, the trunk of a tree affected with the white heart-rot presents an appearance as shown in Plate II and in Plate III, figure 1, representing both the early and the later stages of the disease. It will be noted that the center of the tree has been transformed into a pulpy mass having an irregular outline. This mass is definitely limited on the outside by one or more narrow black layers. In some instances the wood is discolored outside of these black layers. This is more marked in the poplar than in any of the other hosts of the fungus. One of the most characteristic features of the decay of the trunk is that the decayed wood is confined to one large central mass, differing in this respect from the pocket-like destruction brought about by several other wood-destroying fungi, notably *Stereum frustulosum*, which is mentioned later in this paper.

Trees attacked by the false-tinder fungus rarely become hollow, for after the wood has become thoroughly decayed by the fungus it remains in the interior as a pulpy mass. Where hollows do occur, they are caused by various insects which bore through the decayed wood.

SUSCEPTIBILITY OF DIFFERENT HOSTS TO THE WHITE HEART-ROT.

The false-tinder fungus is probably one of the most widely distributed forms of wood-destroying fungi; it occurs on more different species of broadleaf trees than any other similar fungus. Among its hosts are to be found the most important timber trees of the deciduous forests of North America. So far as known to date, the fungus has been found on the following host species: Beech (*Fagus atropunicea* (Marsh.) Sudworth), aspen (*Populus tremuloides* Michx.), balm of Gilead (*P. balsamifera* L.), willow (*Salix* sp.), sugar maple (*Acer saccharum* Marsh.), red maple (*A. rubrum* L.), silver maple (*A. saccharinum* L.), striped maple (*A. pennsylvanicum* L.), yellow birch

(*Betula lutea* Michx. f.), butternut (*Juglans cinerea* L.), black walnut (*Juglans nigra* L.), oaks (*Quercus* spp.), apple (*Pyrus malus* L.), and hickory (*Hicoria* sp.). In Europe it is everywhere prevalent upon the broadleaf trees, but occurs more commonly on the beech (*Fagus sylvatica* L.), oaks (*Quercus* spp.), and alder (*Alnus incana* Medic.).

In this country certain species are almost universally affected with the white heart-rot, irrespective of the region where they are found. An excellent instance is the aspen. This tree, which (72, 99) has the widest range of any species of forest tree in North America, is subject to this disease very generally. *Fomes igniarius* has been found on this host from such extreme points as Maine, western Canada (51), Oregon, Colorado, and southern New Mexico.

In New York and New England the beech has been found to be the most common host of this fungus. Wherever any considerable amount of beech timber is found, white heart-rot is prevalent. In some sections as many as 90 to 95 per cent of the beech trees of merchantable size have been found affected with this disease. Both the butternut and the black walnut are frequently affected. The oaks are quite generally affected, but more especially those belonging to the black oak group.

A marked difference in susceptibility is occasionally found in certain species of the same genus. Thus it has been reported that the aspen is more seriously affected in western Canada than is the balm of Gilead (51). Among the maples it has been found that the striped maple is quite generally attacked in those localities where the disease is present in the same vicinity upon others of its host species. The silver maple seems to be nearly as susceptible as the striped maple, while the red maple and sugar maple are rather rarely affected. The yellow birch is even less frequently attacked than are the red or sugar maples.

DISTRIBUTION OF FOMES IGNIARIUS.

The false-tinder fungus (*Fomes igniarius*) is known to occur throughout the United States. In general, its distribution may be given as follows: In North America it occurs in Alaska, in various parts of Canada, throughout the United States, and in the Bahamas. In South America it has been collected in Surinam, Brazil, Argentina, and Patagonia. It is prevalent throughout Europe from England to Russia, and from Scandinavia and Finland to Italy and Spain. In Asia it is known from Siberia, Japan, the Philippines, and India. It also occurs in Tasmania, Australia, Java, New Zealand, Admiralty Islands, Sierra Leone, and South Africa.

It will be noted that these localities embrace the four quarters of the world. Because of the lack of knowledge of the mycological flora of many countries, no statement can be made as to the occur-

rence of this fungus in them. The recent statement of Schuman and Lauterbach (92) that it occurs the world over can scarcely be doubted.

The amount of destruction caused by this fungus in the North American forests is beyond computation, because of both the wide occurrence of the fungus and the large number of host species upon which it grows. The loss caused thereby differs considerably with the locality and the host species. The greatest losses are brought about in more or less definitely limited localities. There are districts which are very badly affected with this disease, and others which are comparatively free therefrom, which may be considered a good augury from the standpoint of prevention.

Where this fungus occurs extensively almost the entire stand of certain species is frequently found so badly injured with the white heart-rot as to be practically worthless. In a certain area of deciduous forests in the Adirondacks in the State of New York, where the timber was comparatively a mature stand, actual counts showed that from 90 to 95 per cent of the otherwise merchantable trees of beech were rendered valueless from the attacks of this fungus. The same is true to a certain degree in the regions where the aspen is grown extensively for pulp wood. In the New England States, Colorado, and New Mexico it is almost impossible to find healthy groves of aspen which have attained any age, because of the extreme destruction brought about by the false-tinder fungus. In the mature beech stands of Texas and Louisiana, where the trees are 150 years old or more, a very large percentage are wholly decayed in the interior by this fungus. (Pl. II, fig. 1.) The same is true of many of the tracts of the Appalachian deciduous forests. It may be stated that the amount of damage caused by the white heart-rot is very great; and its wide distribution, together with the almost universal susceptibility of deciduous trees thereto, make it the worst enemy of these species, especially during the period when they are approaching maturity.

DESCRIPTION OF THE FUNGUS.

The fungus *Fomes igniarius* has been known for a great many years and has been made the subject of a large number of descriptions, as a result of which a very extensive bibliography has developed, which is too bulky to be here included. It is probably one of the oldest fungi known, as it attracted attention in the early days because of its size and uses. Lightfoot (47) in 1777 made the following statement:

> An excellent touchwood is made from this fungus, by first paring off the outer rind, then boiling the remainder in lye, and afterwards drying and pounding with a hammer, or else pounding and boiling it up with saltpeter. The same fungus beaten into soft square pieces is well known to surgeons by the name of *Agaric*, and has been much celebrated for stopping the bleeding of arteries; it has not, however, proved altogether

successful unless in the smaller vessels. We are informed by Gleditsch that in Franconia he has seen these beaten pieces of Boletus which resembled the softest leather curiously sewed together and made into garments.

The false-tinder fungus has been well known in Europe for about two hundred years. Its synonymy is given below:

Boletus igniarius, Linnæus, C., Species Plantarum, p. 1176. 1753.
Polyporus igniarius, Fries, E., Syst. Mycol., vol. 1, p. 375. 1821.
Fomes igniarius, Gillet, C. C., Champ. France, vol. 1, p. 687, pl. 156. 1878.
Phellinus igniarius, Quelet, L., Enchir. Fung., p. 172. 1886.
Mucronoporus igniarius, Ellis, J. B., and Everhart, B. M., Jour. Mycol., vol. 5, p. 91. 1889.
Pyropolyporus igniarius, Murrill, W. A., Jour. Mycol., vol. 9, p. 101. 1903.

The name *Fomes igniarius* has been accepted and is in general use, while the three later generic names are not so well known or so generally accepted. It seems best to use the more common and better known name in the present account of this fungus.

The false-tinder fungus (*Fomes igniarius*) is one of the most conspicuous of the so-called punks, or shelf fungi, which grow upon living trees. It varies much in shape, size, and color, depending upon its age and upon the species of tree upon which it grows. It is commonly more or less hoof shaped, measuring about as much in thickness as in width. Its size varies from 1 or 2 inches to 12 inches or more in width. The upper surface is smooth in the younger forms and becomes concentrically marked as the fungus grows older. It is characterized by a very hard external layer, which is at first brown, gradually becoming black, and in the older forms is considerably roughened and cracked. The cracks, however, rarely penetrate far into the mass of the sporophore. The sporophores are very woody and of a rusty brown color on the inside. The pores are formed in layers, one below the other, and the sporophores apparently may grow to a great age. The writers have found them with 50 layers. Atkinson (4) reports one with 80 layers. The average number is from 15 to 30 layers, presumably indicating an age of approximately the same number of years. The lower surface is gray to red-brown in color, varying according to the season. The edge is yellowish brown when first formed, and very much lighter in color than the top. Toward the end of the season the newly formed portion weathers considerably above and has a rusty appearance. Although there is considerable variation in the form of the sporophore, its general characteristics are so decided that it is rarely confounded with any of the other wound fungi.

SPREAD OF THE DISEASE.

The white heart-rot, as has been stated, is caused by the growth and development in the wood of the trees of the mycelium of *Fomes*

igniarius. The fungus gains entrance into the trunk of the tree through some wound; in other words, it is a wound parasite of the most distinct type. An examination of thousands of infected trees has shown without exception that there must be some wound before infection will take place. A careful series of observations has furthermore shown that the point of entrance is usually indicated some years later by the location of the oldest sporophores. These sporophores are usually situated on old branch stubs or in holes left when the base of the branch rotted away.

In a large percentage of cases infection takes place through old branch stubs. The spores of the false-tinder fungus germinate on a stub, and the hyphæ grow down through the wood of the stub until they reach the heartwood of the main trunk; from this point they grow both up and down in the heartwood, usually starting near the pith, and advance concentrically outward. The destruction of the wood follows very shortly after the entrance of the mycelium into the trunk, progressing both outward and up and down as long as the tree lives. The time which elapses between the injuring of a tree and infection necessarily varies, depending chiefly upon the presence of spores and climatic conditions.

The formation of sporophores takes place usually at the point where infection originally occurred. This can readily be proved by an examination of the diseased area within the trunk, especially during the early stages of the disease. The formation of sporophores subsequent to that of the first one is determined by the location of the tree, the climatic conditions, the size and vigor of the tree attacked, and the number of side branches which may permit the growth of the mycelium from the center to the outside, thereby making possible the formation of additional sporophores. The number of sporophores which will form on a tree is largely determined by the latter fact. Thus, in the aspen, in which wounds made by the dying of the lower branches are healed over with difficulty, the number of sporophores is very much larger on an individual tree than is the case with trees which heal over such wounds more rapidly, like the beech and the sugar maple. It is not uncommon to find a diseased poplar tree with anywhere from three to twelve sporophores on various parts of an affected trunk (Pl. I); in the beech and birch a smaller number is the rule.

The growth of the mycelium of the fungus is usually confined to the heartwood of the trees. Hartig states that the fungus may enter trees by means of slight wounds in the sapwood, and describes the manner in which the fungus starts its development in the sapwood, growing from the sapwood into the heart. His observations refer to the oak, however, with which comparatively little work has been done in this country.

After the fungus has once obtained a start in the wood of the trunk it may encroach upon the sapwood, and after a time reach the newer sapwood immediately under the bark, thereby causing the death of that portion of the tree, and, when the entire diameter of the trunk is affected, of the whole tree itself. This is especially true of the aspen and the striped maple. As this fungus occurs so generally upon living trees, it has been thought that it would cease growing after the host tree had died. From a large number of observations made by the junior writer it has been found that this is not really the case, for many trees have been found entirely dead and leafless upon which the fungus was still growing vigorously. This is true not only with one or two of the host species, but, so far as could be determined, with all of them. In some cases a vigorously growing new layer was found on the underside of sporophores growing on trees and stubs which certainly must have been dead for a year or more. Standing stumps were also found bearing living sporophores several years after the death of the diseased tree. This finding that the sporophores will continue to develop on dead wood is believed to be of considerable importance, because the dead wood coming from a tree diseased by this fungus in which the mycelium is present must be considered a possible source for further infection of healthy trees.

INFLUENCE OF ENVIRONMENT ON PREVALENCE OF WHITE HEART-ROT.

The possible factors which may influence the distribution and growth of *Fomes igniarius* are many and varied in character. Among them the following deserve consideration: Climate, surrounding forests, character of the soil, species of host, age of host, rapidity of growth of host, rate of healing of branch wounds, and presence of wounds on host.

The climate has very little to do with the distribution and virulence of this disease. It occurs in the humid forests of the eastern United States as well as in the very dry regions of New Mexico and Colorado; and it seems to flourish as well in semitropical and tropical countries as in the colder regions of the north.

The character of the surrounding forest seems to have absolutely no influence upon the frequency of the disease, except as it does or does not contain some of the host species in abundance. The fungus seems to occur with equal frequency in pure stands and in mixed forests. In other words, the aspen is found diseased just as frequently in a mixed stand with other trees as in a pure stand of aspen.

The character of the soil has little or nothing to do with the occurrence of *Fomes igniarius*. The species of the host, on the other hand, has a very considerable influence on the frequency of the occurrence

of the disease. As stated before, the aspen, the beech, and the butternut, in the order given, seem to be the most frequently diseased of all the hosts upon which the fungus has been found.

The age of the host tree is probably the most important factor connected with the distribution of the disease. It has been indicated that the principal mode of entrance of the fungus is through dead branches. Trees which are not old enough to have many dead branches or which are not old enough to shed their lower branches are free from the disease. When a branch dies and is broken off its wood is left exposed to the attacks of the fungus.

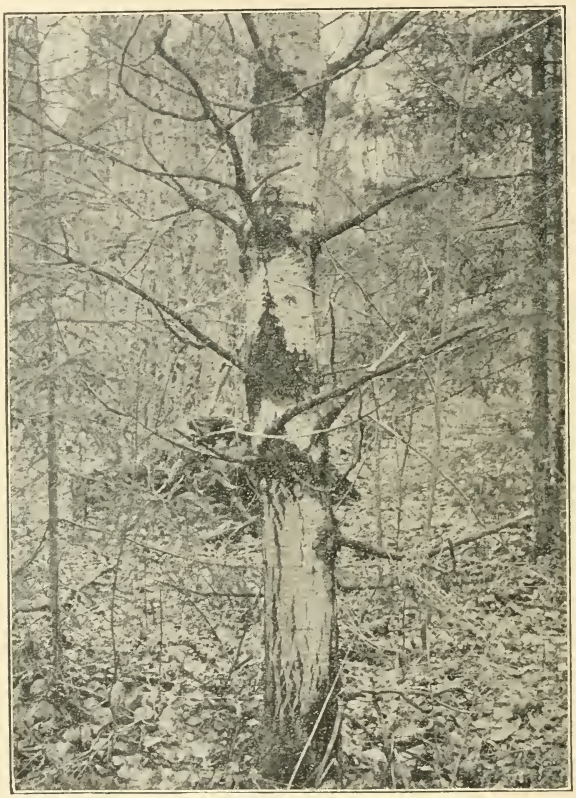

FIG. 4.—An aspen tree with many dead lateral branches; each of these offers a good entrance for wound fungi.

Where trees are very much suppressed the fungus may be found on trees only 1 or 2 inches in diameter; but it will be found on examination that such suppressed trees are in reality of a considerable age. In general it may be said that none of the common deciduous forest trees are affected with the white heart-rot before they are 20 years of age, and most of them will not become affected until they are considerably more than 20 years old. The aspen and the butternut become infected after they are 20 to 25 years of age. This is especially true of the aspen, on which dead branches remain on the lower part of the tree trunk for years after they are dead (fig. 4). A clean-stemmed forest of beech standards will show far less susceptibility when 50 to 60 years old than a similar stand in which the dead branches stick out in large numbers from the lower portions of the trunk.

The chances for the healing of branch wounds are generally very much better for a tree with thick sapwood than for one with thin sapwood. From an examination of trees affected with the white heart-rot the following average ages have been determined as indicating the periods beyond which infection is liable to result: Butternut, about 15 to 20 years; black walnut, about 20 years; aspen, 20 to 25 years; yellow birch, 20 to 25 years; beech, 25 to 35 years; silver maple, about 35 years.

The rate of growth of the host tree affects chances for infection only so far as it influences the rate with which such trees are able to heal wounds. Vigorously growing trees of a certain species will as a rule show less tendency toward infection than slow-growing trees of the same species. Anything which tends toward the healing of the wounds formed in a tree as it grows older will reduce its chances of becoming diseased.

The formation on trees of wounds other than those caused by the natural dying and breaking away of branches on the lower part of the trunk has a material influence on the chances for infection. Short-lived trees, like the aspen, in which with increasing age there is a rapidly increasing tendency for all branches to be broken off by windstorms, show a greater tendency toward diseased conditions as the trees reach maturity and afterwards than is the case with trees such as the beech and oak, which are long lived, where the tendency toward the breaking of the branches, due to ice storms and windstorms, is smaller.

Summing up the factors which control the entrance of the false-tinder fungus, one finds that the chief factors, given in the order of their importance, are: First, presence of wounds on the tree, this involving the natural rate of healing of lateral branches, especially on the lower parts of the trunk; second, age of the tree; and third, greater or less tendency on the part of trees to maintain a close crown, reducing the chances for the breaking off of large branches by windstorms and ice storms.

ULTIMATE FATE OF DISEASED TREES.

A tree affected with the white heart-rot may continue to live for many years, even if badly diseased. This is particularly true of long-lived trees, like the white oak and the beech, and especially if the amount of wood destroyed in the trunk is so small as to reduce the strength of the trunk but slightly. Where the disease encroaches upon the sapwood, as in the case of the aspen, trees may be killed by the disease; and this actually does take place in many instances. The chief destructive results, however, should be considered from the point of view of the wood destroyed by this fungus.

Trees are chiefly grown for the wood which they may produce, and, with the possible exception of shade trees, anything which destroys the heartwood of the tree causes serious loss. These losses increase with the age of the tree, for the older the tree becomes the more wood is destroyed. Ultimately all affected trees are blown over, it being only a question of time before this happens. *Fomes igniarius*, in fact, may be considered one of the chief factors determining the length of life of many of the deciduous forest trees.

EFFECT OF THE FUNGUS ON THE WOOD STRUCTURE.

The diseased wood is very sharply bounded from the healthy wood by black layers about one-eighth to one-sixteenth of an inch in width. (Pl. II.) There may be but a single one or there may be several arranged more or less concentrically. (Pl. II, fig. 2.) Just outside of these layers there is a layer consisting of from three to six annual rings, which is darker in color than the normal wood because of the infiltration into the same of products of the decomposed wood. When there is but a single black layer the rotted wood extends out to this; when there are several such layers the completely rotted wood may extend out only to the inner layer, while between the series of layers the wood will be found in various stages of partial decomposition. These black layers never exactly follow the annual rings of growth. They are usually very irregular, crossing the rings back and forth. The completely rotted wood is white to light yellowish in color, according to the species of tree in which the fungus is growing. When rubbed between the fingers it breaks up into fine flakes, but does not powder. It has lost its strength and can no longer be called wood.

In the completely decayed wood the mycelium of the fungus is abundant in the large vessels and medullary rays. The walls of the wood cells are very much thinner than in the normal cells, and in many places the middle lamellæ are wholly lacking. The addition of chloriodid of zinc shows that the walls which are thinnest are composed of cellulose. In other words, one of the principal effects of the fungus is the solution of the lignin elements of the cell wall. Extending from the large vessels the fungous hyphæ pass freely across the wood cells and between the remnants of the walls, binding them together in a more or less compact mass. In the earlier stages of the disease the hyphæ develop most abundantly in the medullary rays, and from these they pass to the wood cells through the pits. As a rule the hyphæ do not enter the cells at other points by a direct solution of the walls.

Shortly after a hypha has passed through a pit the latter enlarges, forming an irregular hole in the walls, and as the solution of the walls continues two or more such holes coalesce, forming a large opening. At this stage the affected cell walls still retain enough of their lignin

elements to give the lignin reactions. The solution of the middle lamella generally begins near the enlarged pit openings and continues rapidly until the individual fibers fall apart. In the earlier stages of the disease a yellowish substance which is readily soluble in alkalis is present in many of the cells. It is this yellow color which frequently passes outward in advance of the actual destruction of the wood and gives it a darker coloration. In the earlier stages of decay the young mycelium is colorless, but when exposed to the air turns brown.

PREVENTIVE MEASURES.

Since *Fomes igniarius* is a wound parasite, but two methods of prevention can be suggested: One of these consists in the prevention of wounds and the other in the removal of the primary sources of infection. On large forest tracts it is at present impossible to deal with individual trees for the purpose of treating wounds. Much can, however, be done in a general way to reduce the chances of natural wound infection. Attention has already been called to the fact that the tendency toward natural pruning in several species of deciduous forest trees, with a consequent rapid healing of the wounds caused by the breaking away of branches, very materially reduces the chances for infection during the early life history of the tree, the period during which the greatest wood development takes place. The growing of straight, clean-stemmed trees results in a healthier stand, in which the chances for infection are very much less than in a similar stand of the same age where the lower branches are left dead on the trees for many years. It is often practicable to assist the natural pruning tendencies of trees, and where this is possible the results will be correspondingly great.

The most practical method for combating the heart-rot of deciduous forest trees at the present time is undoubtedly the removal of the possible sources of infection. This is especially true of more or less circumscribed areas. Wherever the management of forest tracts is undertaken, one of the first things which should be done is to make a careful search for trees already infected and to promptly remove them.

Where an infected tree is found it should always be cut down. Removing the sporophores from such trees and leaving the trees standing is inadvisable, because when a fruiting body is removed it will soon be renewed, thus necessitating going over the same tract many times, with lessened chances for success. The removal of a diseased tree is furthermore made advisable by the fact that when the sporophores once appear upon such a tree it is a sure sign that the heartwood of that tree is rapidly being destroyed. Where diseased trees are cut in the early stages of infection, as evidenced by

the appearance of but one or two sporophores, it may often be possible to save a considerable amount of wood and lumber. If only the sporophores are removed and the trees left standing, the fungus continues growing in the tree, and every year that such a tree is left in the forest it depreciates in value, and ultimately becomes entirely worthless. The removal of diseased trees should be undertaken no matter to what species they may belong. So far as we now know, *Fomes igniarius* when growing on one host species may infect the others, and in a deciduous forest a diseased maple must be considered a source of danger for the other host species until it is shown that the maple fungus is a distinct form which can not infect other species. In the absence of such proof it is advisable to cut down the diseased maple and make the protection of the remaining trees certain.

Any examination of a forest tract for diseased trees should be made thoroughly, so that all diseased trees may be removed, for the existence of a single tree bearing a number of actively growing sporophores is sufficient to cause the infection of a large area, since the spores of the false-tinder fungus are very light and are blown to great distances by the wind. All diseased wood should be burned, as sporophores continue to develop on diseased wood even after being cut from the tree.

Where trees are sufficiently valuable to warrant their being treated individually, careful wound protection is advisable. Wherever a branch of any size breaks off or where deep wounds are produced in the trunks of trees, such wounds should be carefully trimmed so that the surfaces are smooth. The wounds should then be coated with some good antiseptic substance which can be rapidly applied and which will have sufficient penetrating power to infiltrate for a distance into the wood fiber. The best material for this purpose is coal-tar creosote. This should be heated until thoroughly liquid, when it can be applied with a paint brush. It not only has the distinct advantage of killing all fungous spores which may be present or which may subsequently lodge in the wound, but it is also a good preventive against boring insects.

The painting of wounds is especially advisable where such wounds are large. One instance which occurs to the writers where such wound treatment would have proved very advantageous if it had been carried out in time was in a large tract of chestnut forest. The large trees had been cut out a number of years before the writers' observations were made, and shoots had started from the bases of the old stumps. These shoots were sufficiently old to have formed heartwood. A large percentage of these young trees were found affected at the base of their trunks, the fungus having entered

from the old stump into the heartwood of the living trees. If the stumps had been painted with creosote soon after the trees were cut, this could not have happened.

A similar instance was noted some years ago in a catalpa plantation in eastern Kansas, where the trees had been cut off while they were still young in order to stimulate the production of a single large shoot. The high percentage of diseased trees in this plantation is directly ascribed to the fact that the fungus had entered the new shoots from the old stumps. It would have been easy and comparatively inexpensive to have coated the cut surfaces of the stumps with coal-tar creosote at the time the trees were cut. Where this can be done, especially where coppice growth is expected, as in the case of the chestnut, such wound treatment may be found practicable and will at all times be advisable.

RED HEART-ROT CAUSED BY POLYPORUS SULPHUREUS.

The sulphur polyporus (*Polyporus sulphureus* (Bull.) Fr.) is found on a large number of deciduous forest trees, but chiefly on oaks (*Quercus* spp.), chestnut (*Castanea dentata* (Marsh.) Borkh.), maples (*Acer* spp.), black walnut (*Juglans nigra* L.), butternut (*Juglans cinerea* L.), alder (*Alnus* sp.), locust (*Robinia pseudacacia* L.), apple (*Pyrus malus* L.), pear (*Pyrus communis* L.), etc. It is widely distributed throughout the United States and Canada and in most of the forest regions of Europe, where it is regarded as a destructive parasite, both on deciduous trees and conifers (32). Reference to the disease caused by this fungus was first made in this country by Galloway and Woods (27), and later by von Schrenk (78).

The fruiting bodies of the sulphur polyporus are among the most conspicuous of the larger fungi found in the forests. They form a series of shelves, from 2 to 20 or more, overlapping one another. Sometimes they form very close together, so as to produce a large, round mass about the size of a person's head. (Pl. IV, fig. 1.) The upper surfaces at first are a bright orange-red, with a brighter red at the rims. As they grow older they assume a distinct sulphur-yellow color, which is also the color of the under surface. When young, the upper surface is very moist, somewhat hard, and when bruised turns brown. The whole fungus is soft and fleshy when young, and when squeezed a clear yellowish liquid exudes. As the plant grows older it becomes much harder, and shortly after maturity becomes quite firm and brittle. The fruiting bodies of this fungus very rarely remain on the tree for any length of time, because they are attacked soon after reaching maturity by a number of insects, which speedily destroy them. The fungus is also eagerly sought by mushroom hunters on account of its excellent and well-known edible qualities.

The fruiting bodies of *Polyporus sulphureus* usually occur in some large knot hole on the side of the tree trunk; they are, however, frequently found on stumps and fallen branches. The mycelium of the fungus is capable of living in the dead wood of a tree for many years, and when the proper conditions recur the fruiting bodies continue to form each year, or with a marked periodicity in alternate years. A large branch was broken from a chestnut tree which had been diseased by the sulphur polyporus for many years, and accurate observations were made upon this branch for five years. It was found that in July or August large masses of the fruiting bodies developed from this branch. The fruiting bodies of the sulphur polyporus form on trees and stumps during the middle or latter part of the summer and, as stated, can be found for only a short time.

The destruction which *Polyporus sulphureus* brings about in the heartwood of trees is very similar for all of the host trees upon which it grows, irrespective of whether they are coniferous or deciduous species. The decayed wood resembles a mass of red-brown charcoal. There are various degrees of coloration, depending upon the host, being darker in most of the species of oak and lighter in chestnut and walnut. The decayed wood is characterized by a series of concentric and radial cracks extending irregularly through it. (Pl. IV, fig. 2.) These cracks develop as the wood is destroyed, and are caused by the decrease in volume of the affected wood. The fungus forms thin, leathery sheets in the cracks. In wood which is badly decayed a blow with a hammer will cause the decayed wood to drop out in the form of fine powder, leaving the thin sheets, consisting of densely interwoven threads of the fungus, as a skeleton framework. The decay of the wood itself is a very uniform one; in other words, there is no localized decay, but the wood is uniformly converted into a brown, brittle substance which readily crumbles into a fine powder when rubbed between the fingers. The red-brown coloration, the presence of large white sheets extending throughout the mass of the decayed wood, and the presence of numerous large and small cracks extending radially, tangentially, and transversely through the mass of decayed wood readily enable one to recognize wood destroyed by the sulphur polyporus. In the oaks the broad medullary rays persist longest.

The age at which trees are attacked by this fungus varies considerably with the region in which they are growing and the conditions under which they are situated. Healthy, rapidly growing trees which heal their wounds quickly remain free from the disease much longer than stunted, poorly grown trees. The youngest trees in which the red heart-rot was found were about 50 years old.

Preventive measures consist of essentially the same treatment as is suggested for *Fomes igniarius*. In view of the fact that the myce-

lium of the sulphur polyporus usually enters the trees in the crown, it is hardly practicable to attempt wound treatment. The chief endeavor, therefore, must be concentrated on the removal of the diseased trees. Any tree which shows signs of development of sporophores of *Polyporus sulphureus* should be cut down at once, and all of the wood affected with the mycelium of this fungus should be burned.

PIPED-ROT OF OAK AND CHESTNUT.

The disease which we distinguish under the name "piped-rot" especially affects oak trees, particularly those of the black oak group. (Pl. V, fig. 1.) It has also been found in the beech (*Fagus atropunicea* (Marsh.) Sudworth) and yellow birch (*Betula lutea* Michx. f.). This disease has been found widely distributed throughout the deciduous forests of the Mississippi Valley.

A similar disease, which is probably caused by the same fungus, occurs in the chestnut (*Castanea dentata* (Marsh.) Borkh.). (Pl. V, fig. 2.) The heartwood of affected trees has a mottled appearance, showing irregular, small, pocket-like patches of white fibers, separated by wood fibers still retaining almost the normal color of the heartwood. The white areas first appear in the wood in the form of small lens-shaped areas, which gradually increase in size longitudinally, and after a while become confluent, so that in the course of time the wood frequently shows a series of irregular white lines extending longitudinally. As the disease progresses the white areas change into small pockets, or holes, lined with fibers. Where these holes reach any size, they frequently become filled with a dark, red-brown mycelium. In its last stages the diseased wood is composed of loose masses of white fibers mixed with the brown mycelium and inclosed by thin unaffected layers of wood. The preliminary stages of the disease are characterized by a darker coloration of the heartwood, which starts near the center of the trunk, gradually spreading outward until it reaches the sapwood. In Plate V, figure 1, this darker coloration shows on the boundary between the partially decayed wood and the sapwood.

It will be noted that the disease is confined strictly to the heartwood of the tree. The changes just described originate near some branch stub, very much as has been described for *Fomes igniarius*. Without referring in detail to the microscopical changes which take place in the wood, it may be said that the white areas are due to a lining of cellulose fibers, which stand out more or less separately from one another, on the inner surfaces of the cavities.

The piped-rot is one which is readily distinguished from all other diseases of deciduous trees on account of the speckled character of

the affected wood, and it differs very materially from a somewhat similar disease caused by *Stereum frustulosum*, described later on, by the fact that the white areas in the present disease are not sharply defined, but appear as more or less regular white lines in the mass of the wood.

A disease very similar to the one just described for oaks has repeatedly been found by the senior writer in young chestnut trees, particularly in New York and New Jersey. (Pl. V, fig. 2.) In both the chestnut and the oak the disease first manifests itself in the center of the tree, extending outward until it reaches the sapwood. The white masses, consisting of cellulose fibers, are at first confined entirely to the spring wood of each annual ring. As the disease progresses the changes brought about by the fungus spread into the summer wood of each annual ring, and in advanced stages the entire mass of wood fibers is affected.

Trees of all ages having heartwood are affected with the piped-rot. A number of instances were found of young chestnut trees growing in a vigorous stand which were badly diseased when but from 25 to 30 years old. In the case of the chestnut, the disease frequently starts near the ground line, extending up into the trunk. This is probably due to the fact that the fungus causing the disease obtains entrance into the young chestnut through the old stump from which so many young chestnut trees sprout in the form of coppice shoots. In the oaks the disease is more frequently found originating in the top and extending downward into the trunk.

There has been much discussion as to what fungus is responsible for the piped-rot. In a great majority of cases no fruiting body of any fungus can be found on diseased trees. In many localities in Missouri and adjoining States, where the oaks are severely affected, one frequently finds as many as 50 per cent of the young trees of the second growth affected with this disease; but in spite of this fact not a single fruiting body of any form has been found on the trees.

The piped-rot is especially important in the chestnut. Preventive measures with the chestnut involve coating the stumps of old trees with some preservative, such as coal-tar creosote, so as to prevent the entrance of mycelium into the old stump and thence into the young trees growing from the stump. This coating should be applied very soon after the tree is cut, because after the fungus has once obtained a foothold in the stump it is almost impossible to get rid of it. This, of course, will hold only where chestnut regeneration is brought about by coppice formation. In the case of the oaks the preventive measures suggested for the false-tinder fungus will hold good.

SOFT ROT OF OAKS CAUSED BY POLYPORUS OBTUSUS.

A number of species of the black oaks, notably *Quercus marilandica* Muench. and *Q. velutina* Lam., are affected with a disease of the heartwood which has been determined by Spaulding (94) to be due to *Polyporus obtusus* Berk. Diseased trees have been found in the eastern part of the United States, and notably in the central Mississippi Valley; a large number of trees are usually found affected in a locality.

The spores of the fungus germinate in the burrows of an oak-boring insect (*Prionoxystus robiniae* Peck.). The fungus grows in the borings and follows the insect burrow until it reaches the heartwood of the tree; it then spreads out from this point, both up and down the trunk, and gradually brings about a form of soft rot. (Fig. 5.) The diseased wood is lighter in color than the heartwood of the healthy tree, and in its last stages turns almost white. "The diseased wood retains its fibrous appearance, but breaks much easier than does the healthy wood. It does not have the shrinkage cracks which are so characteristic of some of the wood rots; neither does the affected tissue crumble between the fingers nor break very easily into small flakes" (94). The fungus grows in the trees rapidly, extending up and down in the heartwood and growing outward until it reaches the sapwood. Affected trees are weakened to such an extent within one or two years after their first attack that the slightest windstorm causes the trunks to break.

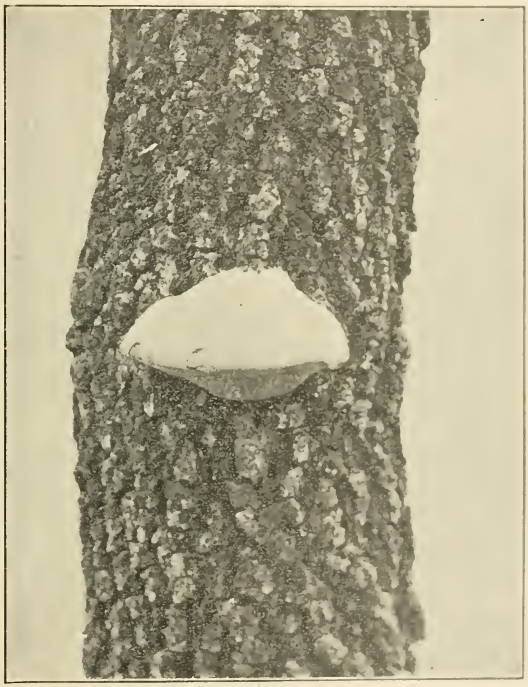

FIG. 5.—A living black oak tree with a sporophore of *Polyporus obtusus* growing out of the opening of an insect burrow.

The sporophore of *Polyporus obtusus* is a very characteristic one. It usually appears at the original insect burrow, where it forms a thick, more or less hoof shaped shelf; in some cases two or three shelves may form, one immediately above the other. The sporo-

phores are almost perfectly white when they first form, but gradually turn darker, and in old age are light brown. The upper surface is very soft and hirsute, and near the point of insertion is much cracked, having the appearance of weathered corn pith. One of the most striking features of the sporophore is the manner in which the rough, hairy upper surface extends over the rounded edge on to the lower side of the sporophore for one-eighth to one-fourth inch or more; the lower surface is the same color as the top. The pores are very irregular in shape, with uneven and jagged edges, giving the whole lower surface a somewhat spiny appearance. The sporophore never attains any great age, because it is attacked with great avidity by various insects which destroy it rapidly.

HEART-ROT CAUSED BY FOMES NIGRICANS.

A brown heart-rot of deciduous trees, especially of the yellow birch (*Betula lutea* Michx. f.), willow (*Salix* sp.), and aspen (*Populus tremuloides* Michx.), is due to *Fomes nigricans* Fr. This fungus is found frequently in the Northern States from Maine to Oregon and occurs most often on the yellow birch. Its method of attacking trees, its rate of development, and its spread from tree to tree are very much the same as those described for *Fomes igniarius*.

The fungus is a parasite in the sense that it attacks the heartwood of the tree, gaining entrance through some wound. The decayed heartwood is reddish brown in color, very soft, and has very much the appearance of wood destroyed by *Fomes igniarius*. Lindroth (48) in a recent description of the changes which this fungus brings about in birch wood notes a number of distinct regions of destruction. In the trees examined by the writers they have not been able to differentiate such distinct zones. Plate VI, figure 1, shows a cross section of a thrifty birch tree, in which it will be noted that the destruction is more or less uniform, beginning at the center of the trunk and extending outward almost to the bark. The decayed wood is spongy and will not powder when rubbed between the fingers.

The most striking feature in connection with this type of heart-rot is the extent to which the decay involves the whole trunk. It starts at the center and progresses outward, gradually involves the sapwood, and ultimately reaches the bark, killing the tree. A similar progress of decay involving the sapwood has already been noted for *Fomes igniarius*. This type of disease is very striking in such trees as the paper birch (*Betula papyrifera* Marsh.). The minute changes which take place in wood destroyed by *Fomes nigricans* are of less interest in this connection; they have been fully studied and described by Lindroth in the article already mentioned (48).

The fruiting bodies of *Fomes nigricans* appear on diseased trees as single, large, more or less hoof shaped bodies; there may be but one of these on a tree, or up to six or eight, but in no case is more than one fruiting body found at one point. The sporophores are large, woody structures, resembling those of *Fomes igniarius*. It has been held by Murrill (58) that *Fomes nigricans* is but a form of *Fomes igniarius*.

The top of the sporophore shows a number of concentric ridges in which large numbers of sharply defined shallow fissures appear as the sporophore grows older. These fissures extend radially and transversely across the top and give the appearance of numerous black lines. The top as a whole is smooth, differing in this respect from many types of *Fomes igniarius*, in the older forms of which the top is very rough; the older portions of the surface are jet black. This is likewise usually true of the younger layers, although we have noted instances where the most recently formed outer edge is dark brown in color. One of the most characteristic properties of the top of the sporophore is its intense hardness. When cut into, this hard layer, which is usually about one-sixteenth of an inch in thickness, has a very characteristic horny texture. The lower surface of the sporophore is rounded, and usually dark brown in color; the pores are very minute and regular. The substance of the sporophore is tough and almost woody. The sporophores are of all sizes, varying from an inch to 10 or 12 inches in width. As a rule, when perfect they are characterized by great regularity in their proportions, and when once recognized, one can hardly fail to distinguish this species.

Fomes nigricans sometimes forms very curious fruiting bodies on birches, the cause for which has not yet been definitely determined. For many years observers and collectors in the Northern States have reported finding irregular, black, jagged masses, having the appearance of dried, hard pitch, growing out from wounds on birch trees (Pl. VI, fig. 2). These masses look like large warts. They are jet black in color, very deeply fissured and broken, and of all conceivable shapes. They increase in size from year to year in a very irregular way without any signs of pore formation. The mass of these bodies is very hard and when examined closely shows that it is composed of masses of dark brown hyphæ the walls of which have become excessively thickened, giving the whole a woody texture. The writers have observed these black structures for a number of years without being able to identify them; the senior writer suggested tentatively, some years ago, that they might be undeveloped sporophores of *Fomes igniarius*.

In his recent paper Lindroth (48) describes similar bodies growing on birches in Europe, and definitely calls them abortive bodies of

Fomes nigricans. While there are no signs of pores or other structures which would enable one to definitely say that these black masses are undeveloped sporophores of this fungus, the writers are inclined to agree with Lindroth that this is the case. This supposition is strengthened by the fact that wherever these black masses occur on birch trees the characteristic decay of the wood usually caused by *Fomes nigricans* will always be found. Attention should be called to the very frequent appearance of these sterile masses—a form of growth, so far as known to the writers, which has not been known for any other wood-rotting fungus.

DISEASE CAUSED BY HYDNUM ERINACEUS.

The coral fungus (*Hydnum erinaceus* Bull.) produces a white rot of many deciduous species, chiefly of oaks. It has been found abundantly on both the red oak (*Quercus rubra* L.) and white oak (*Q. alba* L.), where its large white fruiting bodies form very conspicuous objects (Pl. VII, fig. 2).

The fungus enters the trees very much as do the other wood-rotting fungi, growing from branch stubs into the heart of the tree. It likewise gets in through the tunnels of the oak borer in the same manner as does *Polyporus obtusus.* The diseased wood in its final stages is soft and mushy, so that when squeezed considerable water flows out. Trees in an advanced state of decay have numerous large holes in the heartwood, which are filled with masses of light yellowish, fluffy fungous mycelium (Pl. VII, fig. 1). During the early stages of the disease the heartwood of the oak turns lighter in color, and the more rapid destruction of the wood between the medullary rays is very characteristic of this type of disease. As the disease progresses, the wood becomes spongy and is practically wholly destroyed, so that cavities such as have been referred to form; indeed, the entire heart of the tree may be destroyed, leaving but a hollow shell consisting of sapwood.

The white rot caused by the coral fungus can be recognized by the very wet, soggy nature of the diseased wood. The fruiting bodies of the coral fungus form on broken trunks and on standing trees, issuing frequently from the holes of the oak borer. They are snow-white in color, anywhere from 1 to 10 or 12 inches in diameter, and almost spherical in shape. They may appear singly or in groups. The mass of the sporophores is fleshy, and drops of glistening fluid frequently exude over the entire surface of the top. The top surface is more or less roughly hairy. The bulk of the sporophore consists of an exceedingly large number of white teeth, or spines, bearing the spores.

Very little is yet known as to the exact distribution of this fungus and of the host trees which it attacks. Judging from the number of

times that the writers have found it, particularly in the central United States, it is fairly common on both the white oak and the red oak.

Trees 50 to 60 years old frequently show the soft heart-rot without any signs of the sporophores. The latter appear to form rarely, and after their formation are very short lived, because they are readily attacked by insects. Even where the insects do not destroy them, they dry up very soon after they have reached maturity, and shrivel into insignificant black masses, which can be recognized with difficulty.

BLACK LOCUST DISEASE CAUSED BY FOMES RIMOSUS.

The black locust (*Robinia pseudacacia*) is universally attacked by yellow-rot, which completely destroys the heartwood of living trees. A detailed description of the changes which are caused by this fungus in the wood of locust trees was published by von Schrenk (80). The disease has been found in practically the entire area where the black locust grows, from Massachusetts to New Mexico. It is especially prevalent in the southern Appalachian forests and in some portions of New Mexico, where a very large percentage of the locust trees are destroyed.

Infection takes place through older branches and through the tunnels made by the locust borer (*Cyllene robiniae*). Wounds are frequent in older trees, caused by the brittle nature of the branches of the locust. The fresh wounds are favorable points for the germination of the spores, and it is an easy matter to find all stages, from trees recently infected to trees where the whole side of a trunk has evidently been infected from one branch. The changes which the fungus brings about in the locust wood are very striking. The hard, resistant wood is transformed into a soft yellow or brown mass, which, when wet, is more or less spongy. The almost flint-like character of the wood is wholly gone in completely decayed wood, which can be cut almost like cheese. (80.)

One of the most characteristic features of the decayed wood is that the decay extends out from the center of the heartwood in a series of radial lines. These radial lines are produced by the fungous threads growing outward through some of the large medullary rays.

The sporophores of *Fomes rimosus* Berk. are large and conspicuous. The mature form consists of one or more broad shelves, the top of which meets the lower side at an angle of from 30 to 35 degrees. They are usually almost twice as wide laterally as from front to back. In the Southern States, and particularly in the Appalachian Mountain forests, the sporophores have a decidedly hoof-shaped character, almost as much so as those of *Fomes fomentarius* (Pl. VIII, fig. 1). Similar hoof-shaped forms have been found by Hedgcock in New Mexico. In either form the upper surface in older specimens shows a number of ridges which are very distinct in the younger part of the sporophore, but become almost obliterated as the sporophore grows older. The youngest part of the sporophore shows

a very smooth, rounded edge, which in most cases is light brown, appearing as if polished, or sometimes somewhat villous. The older parts of the upper surface are dark brown, almost black, and are broken into many small pieces by numerous fissures. Many old sporophores have a jagged, extremely rough surface because of these fractures. Lichens and moss frequently cover the older parts. The lower side of the sporophore is dull red-brown and the interior is light brown, with evident, though imperfect, indications of stratification. The pores are continuous through several layers, remaining open for two or three years.

The sporophores often develop from the openings of tunnels of the locust borer or from broken branch stubs. It is not unusual to find eight or ten sporophores on one diseased tree.

Wood which is decayed by *Fomes rimosus* when cut from the tree will remain unchanged for a great many years. In other words, the fungus will not continue to form fruiting bodies on such decayed wood as does the false-tinder fungus previously mentioned. The only preventive measures which can be taken are to care for wounds, and preferably to cut all locust trees before they reach an age where their branches begin to break off in large numbers. For most localities this will be from sixty to seventy-five years.

WHITE HEART-ROT OF ASH CAUSED BY FOMES FRAXINOPHILUS.

A disease caused by *Fomes fraxinophilus* Peck upon white ash (*Fraxinus americana* L.) in the Mississippi Valley has been described in a previous publication by von Schrenk (84). It attacks white ash trees of all ages, usually those, however, which are more than 7 inches in diameter. The fungus is a distinct wound parasite, the parasite starting its development in a branch stub, whence it grows into the heartwood of the trunk. The diseased wood first of all turns darker in color. The next stage of the disease is marked by a bleaching of the color in the spring wood of the annual rings; these gradually turn back to the original straw color, and then white in spots. Ultimately the whole tissue becomes a loose, spongy mass of wood fibers. The completely rotted wood is straw colored, very soft and nonresistant, and readily absorbs water.

The sporophores of *Fomes fraxinophilus* appear at the base of branch stubs or in wounds, either alone or several together. The mature sporophore is nearly triangular in cross section; it has a broad, rounded edge, which at first is white and gradually turns darker until it becomes somewhat straw colored. The older portions of the upper surface are dark brown or black and are very hard and woody. The younger part grows out over the older portions, which makes the sporophore look somewhat sulcate. The main

body of the mature sporophore is very hard and woody. It is obscurely zoned, pale brown and rust colored.

The white ash disease is one that can be combated with success provided careful attention is given to protecting wounds. Vigorously growing trees appear to be particularly susceptible to the disease, since where one diseased tree occurs those in the immediate vicinity are very likely to become infected shortly after. The cutting out of all trees which show signs of sporophore formation is therefore recommended.

RED HEART-ROT OF BIRCH CAUSED BY FOMES FULVUS.

A heart-rot of the river birch (*Betula nigra* L.) has been found repeatedly in Missouri and Arkansas. It is caused by *Fomes fulvus* Fr., which is apparently the fungus which causes such an extensive destruction of the olive trees in Italy. It has been reported in this country on a number of hosts, but especially on the river birch.

The sporophores generally grow near a branch stub. They are very woody and hard. The young sporophore appears as a small knob, which gradually increases in size and when mature is almost triangular in the cross section. The upper surface is at first rough or hairy, but later becomes perfectly smooth and almost flinty in texture. A number of very fine irregular fissures form on the upper surface in older sporophores, extending parallel to the edge. The upper surface never becomes deeply fissured and broken, as in *Fomes igniarius* and *F. rimosus*. The upper surface when mature is a dull red-brown; the lower surface is very smooth and joins the upper at an angle of about 30 degrees. The pores are extremely minute, hardly visible to the naked eye. The mass of the sporophore is very hard and woody and shows decided evidence of stratification. No detailed investigations have as yet been made as to the nature of the decay induced by the fungus. Diseased trees show a brown rot of the heartwood extending for some 10 or 12 feet both up and down from the points where the sporophores are growing. The wood has a red-brown appearance and crumbles to pieces when crushed. There are no signs of felt-like sheets such as occur in similar brown-rotted wood when destroyed by the sulphur polyporus (*Polyporus sulphureus*).

SOFT HEART-ROT OF CATALPA CAUSED BY POLYSTICTUS VERSICOLOR.

The hardy catalpa (*Catalpa speciosa* Warder) is affected with but one very serious disease, which has been described at length by von Schrenk (83). In the early stages of the disease the wood near the center of the tree becomes discolored, and this discoloration gradually

spreads outward. The discolored areas gradually disintegrate until the wood becomes straw-yellow. In the final stages of the disease the entire heartwood becomes converted into a soft rotted mass which resembles pith in its consistency.

The catalpa disease is caused by *Polystictus versicolor* Fr. The spores of this fungus germinate in some wound, or generally at a branch stub. The fungus grows through the stub and spreads up and down in the trunk. After a time fruiting bodies form on the outside of the trunk, generally near a branch wound. The sporophores are sessile and a great many of them grow together, one above the other. They are readily recognized by the soft, hairy upper surface, with alternate bands of light and dark color. The margin of the sporophore is irregularly wavy when dry. Fresh sporophores are fleshy, but as they grow older they become tough and somewhat brittle, and the front edge curls in.

Hardy catalpa trees are affected early in life. In the instances described the trees were about 18 years old. In order to prevent the spread of the disease most attention should be paid to the careful coating of all wounds made in pruning or in cutting off root suckers.

HEART-ROT OF OAKS CAUSED BY FOMES EVERHARTII.

Fomes everhartii Ellis & Galloway (16) has been found repeatedly growing on blackjack oak (*Quercus marilandica* Muench.), causing a disease almost indistinguishable from that described for the false-tinder fungus (*Fomes igniarius*). Affected trees frequently show in a very striking manner that the mycelium of this fungus is capable of growing into the sapwood of the living tree (Pl. III, fig. 2). In the upper part of the figure it will be noted that the fungus has destroyed not only the heartwood but has extended through the sapwood, where it has evidently been growing for about three years, as indicated by the callous formation on the edges of the diseased part.

The sporophores of *Fomes everhartii* are large, conspicuous woody bodies which grow out from wounds. They are generally broad, of a dark rusty brown color, with a deeply cracked and fissured upper surface. The lower surface is red-brown in color, with extremely minute round pores.

WHITE-ROT CAUSED BY POLYPORUS SQUAMOSUS.

Buller (9) has recently described a white-rot of deciduous trees caused by *Polyporus squamosus* Huds., which occurs upon the maple (*Acer pseudoplatanus* L., *A. platanoides* L., *A. saccharinum* L., *A. negundo* L.), pear (*Pyrus communis* L.), oak (*Quercus* sp.), elm (*Ulmus montana* With.), walnut (*Juglans regia* L.), linden (*Tilia europaea* L.),

willow (*Salix* sp.), ash (*Fraxinus excelsior* L.), birch (*Betula* sp.), horse chestnut (*Aesculus hippocastanum* L.), and beech (*Fagus sylvatica* L.). Buller's descriptions refer especially to the occurrence of this disease in Europe; and although the writers have found the same but rarely in this country, it occurs now and then in the Northern States. Freeman (23) mentions its occurrence in Minnesota, although he states that it is usually found on dead logs or stumps. In view of its widespread occurrence in Europe on living trees, it is probable that it will be found in this country more frequently than is known at the present time.

According to Buller, diseased maple wood becomes much whiter than the normal wood. Irregularly scattered series of white lines appear in the diseased wood, resembling the decay brought about by *Fomes applanatus* as described by Heald (38).

The fruiting bodies are almost circular and are attached to the trunk of the tree by a marked stipe. They grow to a considerable size, individuals 1 foot in diameter not being at all infrequent, and Buller mentions a sporophore which measured 2 feet 2 inches across. He states that they are remarkable for their rapid rate of growth.

The fruiting bodies are annual and are produced from May until September. They are at first soft and juicy, but as they grow older and drier they become very tough. The upper surface is characterized by the presence of a series of large scales, which give it a roughened appearance. Buller states that when a tree has been killed by *Polyporus squamosus* the fungus can still continue its annual production of fruiting bodies.

TWO SAP-ROTS.

In addition to the fungi which have been previously described, there are two forms which are usually considered parasitic on deciduous forest trees. These are *Fomes fomentarius* (L.) Fr. and *Polyporus betulinus* (Bull.) Fr. Both of these fungi are very common all over the Northern Hemisphere, and both of them have been described by various authors (Tubeuf (102), Mayr (53), Hartig (34, 35), Freeman (23), et al.) as parasitic on living trees. The manner in which they attack trees, however, is so different from that described for the fungi which cause distinct heart-rots of living trees that they should be considered in a separate group.

In spite of numerous observations which the writers have made for years upon these two fungi, they are not prepared to class them with the preceding forms, nor can they state definitely that they should be considered as parasitic on living trees. Distinction between a parasitic fungus growing on a forest tree and one growing as a saprophyte is a difficult matter. The writers have attempted to make two

groups—one including those fungi which gain entrance through wounds or branch stubs and grow in the heartwood of the living trees; the other, those fungi which grow on dead wood, including both wood removed from the living tree and in some cases dead heartwood or sapwood actually exposed to the air, but still forming a part of the living and actively growing tree. While the first class is not distinctly parasitic in the ordinary sense that a rust is parasitic on a living leaf, the fungi are nevertheless always associated with living trees, and their mode of life may be called parasitic.

Fomes fomentarius and *Polyporus betulinus* rarely, if ever, cause a heart-rot; that is, they rarely gain entrance through a branch stub into the center of the tree and cause a type of decay starting at the center and extending outward. Both of them are found as frequently (and probably in the greater number of cases) on dead trees or logs as they are on living trees. The writers have found both of these forms growing on living and on dying trees, but they are unable to say whether these trees were weakened by the fungi or whether the fungi were able to grow upon the trees because they were already weakened by other causes. The sporophores of both of these fungi grow in large numbers on standing dead trees, and they have frequently been held responsible for the death of trees. The most exhaustive investigation of one of these fungi was made by Mayr (53), who transplanted wood infected by the mycelium of *Polyporus betulinus* into the sapwood of healthy trees and found that in a period from August to November the mycelium had grown 2½ centimeters into the sound wood around the point of infection. He regards this as evidence of the parasitic nature of the fungus, but the final results should be known before passing judgment upon his experiments.

In view of the common occurrence of these fungi, they are described with the expectation that further investigation may decide their true nature.

DECAY CAUSED BY FOMES FOMENTARIUS.

Fomes fomentarius (L.) Fr. occurs in the United States mainly on the beech (*Fagus atropunicea* (Marsh.) Sudworth) and the yellow birch (*Betula lutea* Michx. f.), but it also occurs on other deciduous species. The sporophores are distinctly hoof shaped. They appear as small rounded knobs on the surface of the trunk; that is, they are not confined to branch stubs, but occur also at other wounds. Their upper surface is smooth and more or less definitely marked by concentric ridges. The older sporophores are uniformly gray and have a somewhat powdered appearance. The lower surface is red-brown and shows numerous regular small round pores. The

margin of the newer layer is grayish white and very soft and velvety. The sporophores usually occur singly, although two or more may grow into an irregular mass where they grow out from the trunk in close proximity to one another. A diseased trunk bears from one to twenty or more of the sporophores scattered over the surface. The decay induced by *Fomes fomentarius* starts in the outer sapwood immediately under the bark, and proceeds inward until it reaches the center of the tree. (Pl. VIII, fig. 2.) The decayed wood is characterized by numerous irregular black lines, bounding areas of wood not yet completely decayed. Wholly rotted wood is very soft and spongy, light yellowish in color, and crumbles between the fingers into numerous separate wood fibers.

Beech and birch trees are usually decayed in the tops, and the fungus gradually spreads down toward the base of the trunk. It is no unusual sight to find a large tract of birches weakened by forest fires in which almost every tree has from two to ten sporophores of this fungus growing at various heights from the ground. In northern New England, New York, Michigan, Wisconsin, and Minnesota in particular, the tinder fungus (*Fomes fomentarius*) is one of the commonest wood-destroying forms found in deciduous forests. It grows with great rapidity in dead wood. Beech or birch trees which have been felled are rapidly destroyed by the mycelium of this fungus. The mycelium will develop in large masses from cut surfaces of trunks infected therewith when placed in moist surroundings. This power on the part of the mycelium to flourish away from the standing tree is very characteristic of this species and also of *Polyporus betulinus*.

DECAY CAUSED BY POLYPORUS BETULINUS.

So far as known *Polyporus betulinus* (Bull.) Fr. occurs only on species of birch. It is widely distributed in Europe and Asia and all over the northern part of North America, including the northern United States. In this country it occurs on the yellow birch (*Betula lutea* Michx. f.), the paper birch (*B. papyrifera* Marsh.), and the white birch (*B. populifolia* Marsh.). The fruiting bodies form half-rounded, conspicuous brackets, which start as small rounded knobs, usually growing out through a lenticel. These knobs rapidly expand until they form a hemispherical papery sporophore. (Pl. IX, fig. 1.) The upper surface is very smooth, usually dirty white in color, with no signs of marks or cracks; it resembles a very thick, stiff piece of pasteboard. The outer margin is round and is usually more or less white wherever the thin, dark outer layer has peeled off. The rounded margin extends down on to the lower surface, forming a decided ridge around it. The lower surface is yellowish

to brown in color. The pores are irregularly jagged and toward the outside assume a more or less horizontal position. The sporophores grow to be large—in some cases as much as 12 inches in diameter. They are annuals and are usually short lived, because they are attacked by insects with avidity.

The decay caused by the birch fungus is very similar to that described for *Fomes fomentarius*. The fungus gains entrance through the bark, probably through the lenticels or wounds, and starts growing in the outer sapwood, progressing inward toward the center. (Pl. IX, fig. 2.) The decayed wood is very uniformly yellowish in color and shows numerous cracks extending both radially and tangentially throughout the mass. Badly decayed wood crumbles into a fine powder, and differs in this respect from birch wood destroyed by *Fomes fomentarius*. Mayr (53) discusses the various microscopic changes caused by this fungus in birch wood, treating not only the morphological but also the chemical changes induced by this fungus.

Wherever birch trees are weakened either by fire or other causes, the birch fungus will attack them with great rapidity, and it must be considered as one of the most destructive fungi to birch wood.

SAP-ROTS OF SPECIES OF DECIDUOUS TREES.

The line between those fungi which are capable of growing on dead wood that has died after being cut from a living tree and the fungi which grow on dead wood of the still living tree can not be sharply drawn. Certain of the wood fungi cause disease while the tree is still standing, and where such fungi have universally been found associated with a certain type of disease the evidence is strong that the fungus causes the disease.

In many recent descriptions of diseases of forest trees reference is made to fungi which in the opinion of the writers must be considered strictly saprophytic forms which occur only on dead wood. A striking instance of this is *Fomes applanatus* (Pers.) Wallr. This fungus is frequently found on living trees, but a careful examination always shows it to be growing on wood which is actually dead, and generally on the dead outer sapwood. So far as the writers have been able to observe *Fomes applanatus* does not cause what may be called a disease of living trees. The same is true of many other fungi—for instance, *Daedalea quercina* (L.) Pers., *Polystictus pergamenus* Fr., *P. hirsutus* Fr., *Poria vaporaria* Fr., *Polyporus gilvus* Schweinitz, and *Stereum frustulosum* Fr. It is natural that observers should describe some of these fungi as being responsible for diseases of the living tree, because they occur frequently on standing trees which are but partially alive. The writers believe, however, that most of these forms, if not all, will not grow on a tree until it has already been so weakened

by other factors that to all intents and purposes it is dying or dead, with the possible exception of cases where the fungi grow on dead patches of wood caused by some injury, as in the case of trees injured by fire.

SAP-ROT CAUSED BY POLYSTICTUS VERSICOLOR.

Of all the fungi which grow upon the deciduous species of woods after they are cut from the tree the most widely distributed, and in many respects the most destructive, is *Polystictus versicolor* (L.) Fr. Either singly or in dense masses its varicolored sporophores may be found on any of the deciduous species in all parts of the world. So far as known, this fungus is a strict saprophyte, except where it causes the destructive heart-rot of the catalpa. This fungus grows universally throughout the United States, and probably in all parts of the world. It is extremely common in Canada, Mexico, and Europe; it is known from Africa to Australia, and it has been reported from Japan, the Canary Islands, the West Indies, and South America.

Polystictus versicolor is one of the most cosmopolitan species of fungi known. It does not seem to have any preference for any particular kind of wood, but grows with almost equal readiness, especially on the sapwood, on every broadleaf species of wood (as distinguished from coniferous wood) known. On account of its wide geographical range and its ability to grow on and destroy so many different kinds of wood, it should be regarded as the most serious of all the wood-rotting fungi which attack the dead wood of broadleaf trees. It is the fungus which destroys probably 75 per cent or more of the broadleaf species of timber used for tie purposes. Wherever broadleaf species of wood are used for fencing, for posts or poles, or for any purpose where they come in contact with the soil they are sure to be attacked sooner or later by *Polystictus versicolor*.

The fruiting bodies of this fungus are extremely variable, depending upon the kind of wood upon which they grow and upon the conditions under which they develop. The sessile sporophores may grow singly or, more usually, many of them together, forming a series of closely overlapping shelves. As just indicated, they are readily recognized by the soft, hairy upper surface with bands of various colors. These bands are usually white and yellow, although considerable variation from both of these colors will be found. When young the sporophores are fleshy, but they become tough and leathery when older. The lower side of the sporophore is generally snow white, and the pores are exceedingly regular and minute. The body of the sporophore is very thin, rarely exceeding the thickness of heavy paper.

In the majority of cases the sporophores form on a vertical surface and spring from a broad sheet of mycelium which covers the entire

surface of the timber upon which they happen to be growing. They form readily in a moist atmosphere. They first appear as tiny masses of mycelium, which grow out usually from the medullary rays, and generally several within a small area. These small masses rapidly grow larger, until in the course of a few days they have united in a single mass visible to the naked eye. After they reach the size of one-eighth inch in diameter, or thereabouts, the hymenial layer begins forming on the lower surface of the knob. A mature fruiting body may be formed in about a week where the fungus is in a condition for rapid development.

The young sporophores seem at first to grow perpendicularly from the surface from which they protrude, irrespective of whether this be a horizontal or a vertical surface. Very soon after their appearance, however, the shelves assume a horizontal position. Where wood is placed in contact with the ground, the sporophores are frequently cramped and crowded by soil or stones, and in such cases the growing mycelium adapts itself to the available space and produces sporophores of every conceivable shape and size. It is not at all uncommon to find large masses of the sporophores forming in the upper surfaces of cinder ballast on railroad tracks. The mycelium in this case binds the individual cinders together, forming great clumps 6 or 8 inches in diameter. Where two or more sporophores start on a surface in close proximity they will as a rule fuse before reaching maturity, and as a result of this fusion long sheets may form composed of two or many sporophores which have grown together laterally (fig. 6).

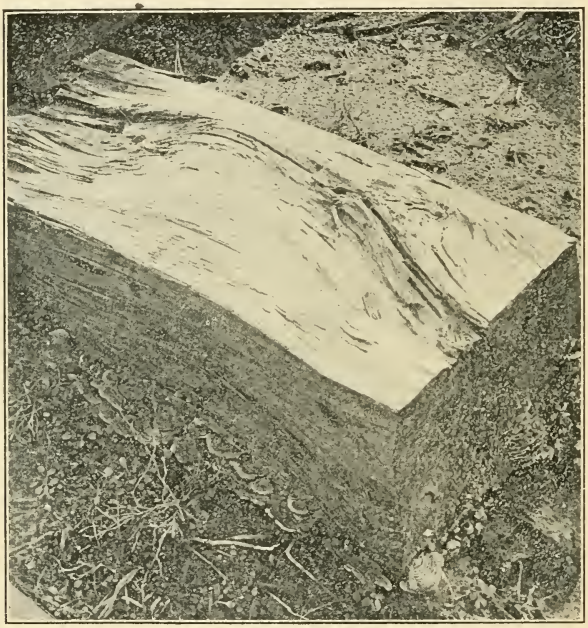

FIG. 6.—An oak railroad tie with fruiting bodies of *Polystictus versicolor*.

Polystictus versicolor usually starts its development in some season check, although it may start to develop on the surface of a stick of wood provided the same is kept in moist surroundings. The spores

germinate where a sufficient amount of water and air is available, and the rapidly growing hyphæ spread through the wood, starting with the medullary rays. The fungus first of all attacks the sugars and starches stored in the sapwood, and then it attacks the woody fiber itself.

The character of the growth of *Polystictus versicolor* is well shown in figure 6. In its early stages the affected wood usually becomes paler in color, and following very soon after this bleaching effect the wood begins to take on a disintegrated appearance, so that it becomes what is known popularly as "punky." It has lost all of its usual characteristics of hardness and strength and has turned into a soft, dry, nonresistant, pithy mass, which is usually more or less straw colored.

The minute changes which take place in the wood fiber consist of a rapid solution of various parts of the woody structure in its entirety. In other words, the fungus has no special preference for either the lignin or cellulose parts of the cell wall. Now and then one may find a condition in the last stages of decay in which some of the wood fibers have become delignified. When such wood is stained with chloriodid of zinc the whole wall of certain groups of wood fibers seems to be corroded away. In badly decayed wood the only parts of the original cell which remain recognizable are those parts of the original walls common to two or three cells. Among the partially consumed fragments of the original wood cells one may find scattering complete cells; in fact, there is no difference in the extent and degree of decay in different parts of the same annual ring. The more open spring wood falls apart more readily because of its porous nature, but no evidence has been obtained that it decays more rapidly than the denser summer wood. The changes just referred to are practically the same for all classes of woods affected.

Like all sap-rotting fungi *Polystictus versicolor* is especially dependent for its development upon the presence of a sufficient quantity of water and air. It will usually grow with the greatest vigor close to the surface of the soil. Its fruiting bodies may therefore be looked for at or near the ground line on ties, poles, posts, and all timbers exposed to the soil. Where wood has time to dry out partially on the outside after it is cut, the spores will not usually germinate on the outside, on account of lack of water. Infection of such partially dried wood usually takes place through some season check.

This fungus may start development in a stick of wood within a few weeks after it has been cut; or, in other words, shortly after the wood becomes sufficiently dry on the outside to form season checks. After it has once gained entrance below the surface, the mycelium will grow vigorously in the wood and give absolutely no evidence of its

presence on the outside until the wood has become sufficiently decayed to permit of the formation of sporophores, which then usually form by growing out through the season checks to the outside air. It is on account of its ability to produce decay in the interior of the stick of wood that this fungus is so very destructive, and it is for this reason that the greatest care should be taken to guard against its possible entrance. In moist climates the fruiting bodies will form above the ground on wood which may be several feet above the soil. Where wood has a chance to have air circulate around it continuously, however, the possibilities that it will become infected with this fungus are remote.

The decay which *Polystictus versicolor* brings about in wood is usually confined for a year or more to the sapwood, and in many species it is wholly confined to the sapwood. This is true of such trees as have their heartwood sharply differentiated from their sapwood, as in the oaks (*Quercus* spp.), black walnut (*Juglans nigra* L.), red gum (*Liquidambar styraciflua* L.), etc. In woods where the differentiation between heart and sap wood is indistinct, as in the tulip poplar (*Liriodendron tulipifera* L.), willows (*Salix* spp.), and cottonwood (*Populus deltoides* Marsh.), the fungus brings about the destruction of the sapwood with great rapidity, and even destroys the heartwood, although this takes place more slowly. Between these two extremes there are many gradations. Sapwood of the white ash (*Fraxinus americana* L.), yellow birch (*Betula lutea* Michx. f.), and beech (*Fagus atropunicea* (Marsh.) Sudworth) is rapidly destroyed, but the heartwood resists the attacks of this fungus for a considerable period of time, although not so long as does the heartwood of the oaks. The rate at which the sapwood of different broadleaf species decays presents little variation. It may be stated as a general rule that the sapwood of all trees is very susceptible to the attacks of *Polystictus versicolor* and that where any difference in the resisting power of such woods to this fungus occurs it will be in favor of the heartwood.

Measures for preventing or arresting the development of *Polystictus versicolor* will be considered later, together with other sap-rotting fungi, because preventives which apply to this fungus will apply to practically all of the sap-rotting forms.

SAP-ROT CAUSED BY POLYSTICTUS PERGAMENUS

A second form of sap-rot of great importance is caused by *Polystictus pergamenus* Fr. This fungus, while usually found on dead wood, may now and then occur on living trees where these have been severely injured. It is one of the forms which frequently appear on standing trees after forest fires have killed certain parts of the

trunk. The forest fire may not seem to have injured the tree at the time, although the heat may have been sufficient to kill the cambium layer over a considerable area. The bark over such areas dries out and cracks, and it is in such dead bark that this fungus finds a favorable entrance. Within a few months after the injury the sporophores of *Polystictus pergamenus* are found growing on the dead bark, and the decay caused by the fungus extends rapidly throughout the deadened area (fig. 7). In almost any burnt area of deciduous forest one may find many of the standing trees after a year or two bearing large masses of the sporophores of this fungus.

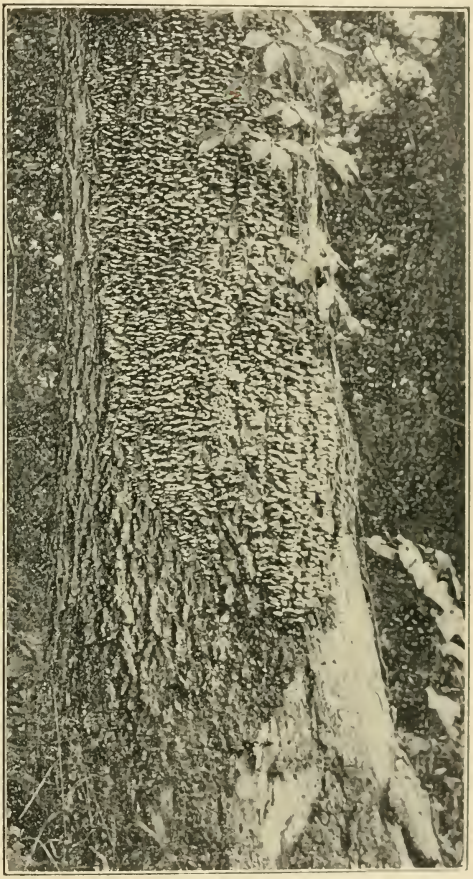

FIG. 7.—A living tree of red oak the bark of which was killed by fire. The fungus *Polystictus pergamenus* is rapidly rotting the sapwood beneath.

Polystictus pergamenus is universally distributed throughout the United States and Canada, and it is known from various points in South America. It grows on practically all the deciduous species of wood. It is very common on species of oak and has been collected by the writers on the following woods: Red gum (*Liquidambar styraciflua* L.), white oak (*Quercus alba* L.), scarlet oak (*Q. coccinea* Muench.), red oak (*Q. rubra* L.), black-jack oak (*Q. marilandica* Muench.), shingle oak (*Q. imbricaria* Michx.), sugar maple (*Acer saccharum* Marsh.), silver maple (*A. saccharinum* L.), red maple (*A. rubrum* L.), yellow birch (*Betula lutea* Michx. f.), chestnut (*Castanea dentata* (Marsh.) Borkh.), shagbark hickory (*Hicoria ovata* (Mill.) Britton), tulip poplar (*Liriodendron tulipifera* L.), black cherry (*Prunus serotina* Ehrh.), beech (*Fagus atropunicea* (Marsh.) Sudworth), and willow (*Salix* sp.).

The general appearance of wood decayed by this fungus is very similar to that destroyed by *Polystictus versicolor*. The microscopic changes differ in certain respects. A cross section of oak wood cut so as to include both healthy and badly decayed wood shows areas of the wood fibers, especially in the summer wood of the annual ring, which are colorless, while the other parts of the section are more or less yellow. The colorless parts are the rotted regions, and in very badly affected wood they may include all of the wood fibers in an annual ring. The vessels and the medullary ray cells, however, retain their color and appear unaffected. When stained with cellulose reagents like chloriodid of zinc the colorless areas stain deep blue. From this it appears that the fungus removes the lignin elements from the cell walls. In the worst affected areas the cells are broken down still further and the walls appear broken and corroded, so that little remains except small fragments of the cell walls with the pieces of the middle lamella which are located at the corners of these cells embedded within them, and the whole held together by masses of fine fungous hyphæ. The medullary ray cells resist the action of the fungus longer than any other part, very much as is the case in the form of decay caused by *Polystictus versicolor*.

The rate of decay caused by this fungus is very much like that described for *Polystictus versicolor*. Small pieces of oak wood inoculated with spores of the fungus have been completely rotted in about three months. The rate of decay varies with the amount of water left in the wood, the air supply, and the temperature.

The relative resistances of heartwood and sapwood to the attacks of this fungus are very similar to those already referred to for *Polystictus versicolor*, and the same may be said of the relative resisting power of different species of woods, so far as known at this time.

The fruiting bodies of *Polystictus pergamenus* occur throughout any deciduous forest tract. A large number usually grow together, one above the other, and not infrequently they are joined laterally so as to form long series of shelves. The body of the pileus is leathery and rigid; the top is concentrically sulcate, generally white when young, growing grayish when older; the upper surface is slightly hairy; the lower surface is generally purplish in color; the pores are small and the intervening walls become much torn and lacerated, so that in older specimens they resemble teeth or spines.

SAP-ROT CAUSED BY FOMES APPLANATUS.

In a recent paper Heald (38) describes a disease of the cottonwood due to *Fomes applanatus* (Pers.) Wallr., which he, however, calls *Elfvingia megaloma* (Lév.) Murrill. He finds that cottonwood trees are affected with a disease which attacks both heart and sap wood and

results in their gradual destruction, ultimately causing the death of the entire tree. The injury to the wood is only local, occurring generally near the base of the trunk. The fungus is said to enter the trunk through injuries near the ground line or through wounds on the roots, and "spreads upward through the entire wood, reaching, in specimens observed, the height of 10 feet. The entire wood of the lower portion of the trunk becomes thoroughly infected before the fungus obtains sufficient vigor to produce its external fruiting bodies. In this condition the wood is rendered very brittle, and the tree thus affected is poorly fitted to withstand the force of the wind in severe storms" (38).

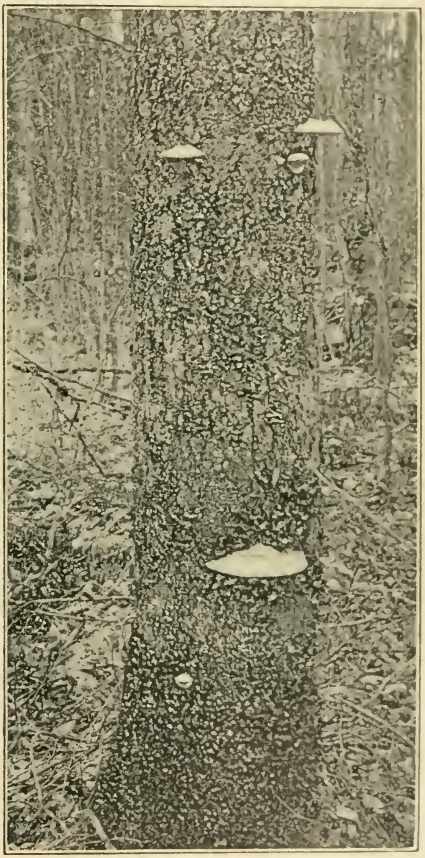

FIG. 8.—A dead stub of a maple tree bearing fruiting bodies of the sap-rot fungus (*Fomes applanatus*).

The diseased wood is characterized by the appearance of numerous localized pockets, separated from one another by wood which the fungus has evidently not been able to destroy. Heald states that the fungus is probably only a facultative parasite and "is not able to attack young, healthy trees, but that it can become parasitic on older trees in which the vitality has been considerably lowered, or that have reached the maximum of their development."

The writers have repeatedly observed this form of decay in the cottonwood, but in their experience it usually starts near the base of the trunk in large wounds caused by fire or otherwise. On that account they are not inclined to call this decay of the cottonwood a disease in the sense in which the decays induced by *Fomes igniarius*, *F. fraxinophilus*, and others are diseases. There are a large number of species of fungi which, like *Fomes applanatus*, grow on dead wood and which may now and then grow on living trees. All of these, including *Fomes applanatus*, can grow just as well and apparently better on wood after it has been cut from liv-

ing trees, and should, in the opinion of the writers, be considered as saprophytic forms. (See fig. 8.)

DECAY CAUSED BY STEREUM FRUSTULOSUM.

Stereum frustulosum (Pers.) Fr. and other species of Stereum cause the destruction annually of large quantities of structural timbers. The fruiting bodies of this fungus are very insignificant and generally escape the attention of the casual observer. They appear in the form of small, slightly elevated gray spots on the surface of decaying wood. In the majority of instances they look like sheets of cracked mud, the individual pieces separated by the cracks vary-

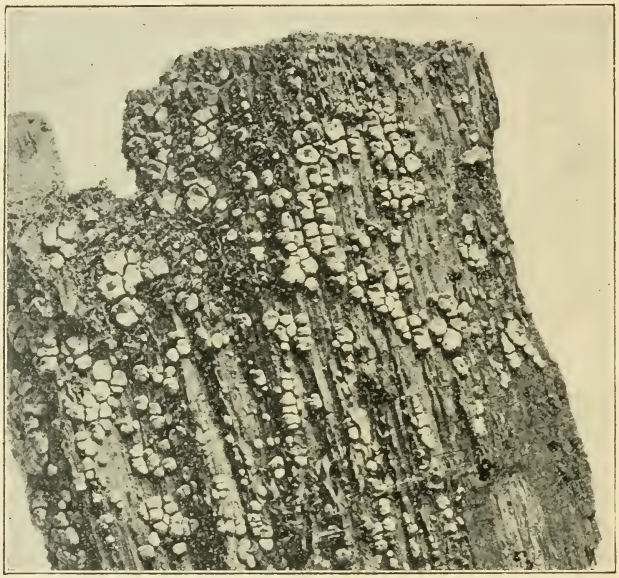

FIG. 9.—A piece of oak timber rotted by *Stereum frustulosum*. The fruiting bodies are the lighter colored, irregular, small bodies which are seen thickly scattered over the surface.

ing in size from one-sixteenth to one-fourth of an inch in diameter. Figure 9 shows a piece of red oak (*Quercus rubra* L.) with the fruiting bodies of this fungus.

Wood decayed by *Stereum frustulosum* can always be recognized by the peculiar pocket-like formation in the mass of the wood. Fungi like *Polystictus versicolor* produce a form of rot in which the entire mass of the wood is affected. *Stereum frustulosum*, on the other hand, causes changes in the wood fiber in localized areas of the wood. The holes are more or less lens shaped and are separated from one another by sound layers of wood fiber. The lining of the holes is usually composed of a layer of white cellulose fibers. *Stereum frustu-*

losum occurs on practically all of the oaks, and probably on other broadleaf species. It is sometimes found growing in wounds on living trees, but is strictly confined to dead wood. It is widely distributed in the United States and is one of the chief fungi destroying oak wood.

SAP-ROT CAUSED BY DAEDALEA QUERCINA.

One of the most important enemies of structural oaks (*Quercus* spp.) and chestnut (*Castanea dentata* (Marsh.) Borkh.) is *Daedalea quercina* (L.) Pers. Plate X shows an end view of a white-oak tie with the sporophores of this fungus; also a section of the same tie 2 feet from the end. This fungus has a world-wide distribution. It is one of the most common forms on oak and chestnut logs, ties, telegraph poles, fence posts, bridge timbers, etc., all of which it destroys with rapidity. The conditions favoring the spread of this fungus, the manner in which the wood is infected, and the rate of growth are in a general way very similar to those described for the two preceding fungi. The sporophores form either singly or in groups. They are sometimes found growing out from large wounds upon the sapwood of standing trees; hence, this fungus has been frequently described as one causing a disease of living trees. The sporophores are tough and rigid, with a corky consistency. They are first white in color, but gradually turn darker to a gray; the upper surface is zonate; the pores are elongated and have a wavy outline.

The wood decayed by this fungus is generally moist and mushy, but on drying becomes harder, although when rubbed between the fingers it crumbles into a fibrous mass.

OTHER SAP-ROTTING FUNGI.

In addition to the sap-rotting fungi referred to there are a large number which grow more or less frequently on broadleaf species of wood. Their number is so large that it is impossible to refer to all of them here, and only a few of the more typical ones can be mentioned. Among these are the following: *Polystictus hirsutus* Fr., *P. sanguineus* (L.) Mey., *P. cinnabarinus* (Jacq.) Fr., *Poria subacida* Peck., *P. vaporaria* Fr., *Polyporus betulinus* (Bull.) Fr., *P. gilvus* Schwein., *P. adustus* (Willd.) Fr., *Lenzites corrugata* Klotzsch, *L. vialis* Peck., and *L. betulina* (L.) Fr.

All of these forms and many others grow singly or, more frequently, in masses on dead wood, which they destroy with varying degrees of rapidity. The manner in which they enter the wood and the rate of growth differ slightly for the different forms, but for practical purposes they need not be distinguished from *Polystictus versicolor* and *P. pergamenus*. Detailed studies of most of these forms are yet to be made. Some of the forms which attack beech wood have recently been described by Tuzson (103).

DECAY OF STRUCTURAL TIMBER.

After the wood from any of the broadleaf trees has been cut from the tree and it is exposed to the air or soil, decay occurs sooner or later. Different species show a varying power of resistance to decay when thus exposed, and as a result of this difference these woods are usually classed into long-lived and short-lived woods. The long-lived woods possess natural inherent qualities which enable them to resist the attack of decay for a comparatively long period. In comparison with many coniferous woods, the broadleaf species have a very much smaller power to resist decay, and the number of them which are long lived is rather few. Among those woods which may be considered very long lived are the catalpa (*Catalpa speciosa* Warder), black locust (*Robinia pseudacacia* L.), and Osage orange (*Toxylon pomiferum* Raf.). Woods like the white oak (*Quercus alba* L.), chestnut (*Castanea dentata* (Marsh.) Borkh.), and shagbark hickory (*Hicoria ovata* (Mill.) Britton) come next in durability; while among the very short lived woods, the willows (*Salix* spp.), cottonwood (*Populus deltoides* Marsh.), beech (*Fagus atropunicea* (Marsh.) Sudworth), and tupelo gum (*Nyssa aquatica* L.) may serve as examples.

CAUSES OF DECAY.

The decay of wood after it has been cut from the living tree may be due to a number of causes. It may crumble away because of influences usually referred to as "weathering." Wood fiber when exposed to the air and to frequent wetting by rain is worn away mechanically, giving the surface a roughened appearance. The wood of most broadleaf species after being exposed turns grayish white in color on the outside, due to the separation of groups of wood fibers which stand out from the surface and give it a more or less hairy appearance.

The principal cause of decay is the growth of certain saprophytic fungi in the wood fibers, which as a result of their growth bring about changes in the wood which alter its structure and tensile quality.

FACTORS FAVORING DECAY.

The factors which favor the decay of wood in general have been repeatedly referred to (79, 81) as (1) a certain amount of water, (2) a certain amount of heat, (3) a certain amount of air, and (4) a certain amount of food supply. Where one or more of these four factors are absent, decay will not be possible, because the growth of the wood-destroying fungi is prevented.

RATE OF DECAY.

The rate of decay varies according to the species of wood and the part of the tree from which it is taken. Sapwood decays very much more rapidly than heartwood. In many broadleaf species the sapwood may be attacked by one or more of the wood-destroying fungi within a few weeks after the wood is cut. The most notable examples of the rapid decay of the sapwood are to be found in timbers like beech (*Fagus atropunicea* (Marsh.) Sudworth), red oak (*Quercus rubra* L.), and chestnut (*Castanea dentata* (Marsh.) Borkh.). The relation which the presence of organic matter in the sapwood has to its decay has been a much discussed question. It has generally been thought that sapwood will decay most rapidly when cut from the tree during the period when the organic matter, such as starches and sugars, is present in the largest quantities and is being actively

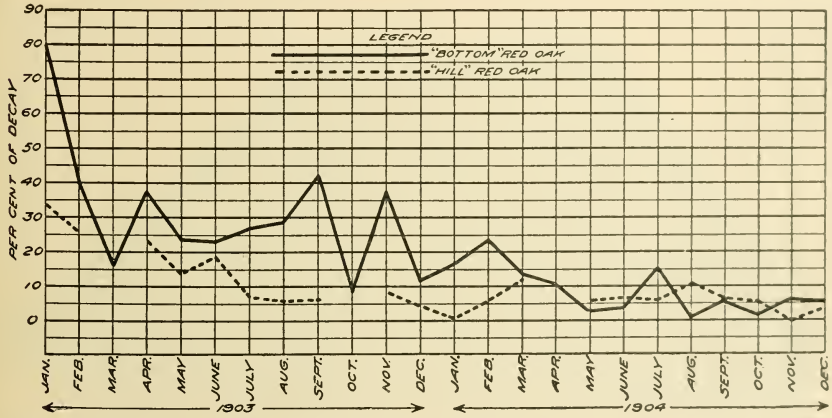

FIG. 10.—Diagram showing relative rate of decay of 2,400 pieces of "hill" and "bottom" red oak. Countings made April 26, 1906.

formed by the tree; that is, during the spring and early summer. This has given rise to the almost universal practice of requiring structural timber to be cut during the winter period, in order to insure a long life.

From a number of experiments made on a large scale with red oak the writers found that the idea that material cut in the winter was less susceptible to fungous attack certainly did not hold in all cases. Reference to figure 10 shows that red-oak timbers cut in November, 1903, decayed more rapidly than did similar timbers cut from the same land and piled in the same locality in June, 1903. While this single experiment does not necessarily show that summer-cut wood is preferable to winter-cut wood, it indicates very clearly that many of the ideas held for a long time as to the relative value of winter and summer cut wood deserve more extensive and careful investigation.

MANNER OF INFECTION.

One of the most practical questions in connection with the decay of sapwood of broadleaf species, as well as of conifers, deals with the manner in which the sapwood becomes infected with the fungus. With the possible exception of some of the fungi referred to in a previous part of the bulletin, such as *Fomes igniarius* and *Polyporus sulphureus*, most of the fungi which bring about the decay of structural timber do not grow in living trees. The heartwood of the living tree is accordingly free from the supposed germs of decay, and wherever any decay does take place the spores of the fungi responsible for the same must get into the wood from the outside.

Although this has been very definitely shown to be the case, there is still a very widespread belief among timbermen that decay starts in the interior of the stick. This has arisen from the fact that pieces

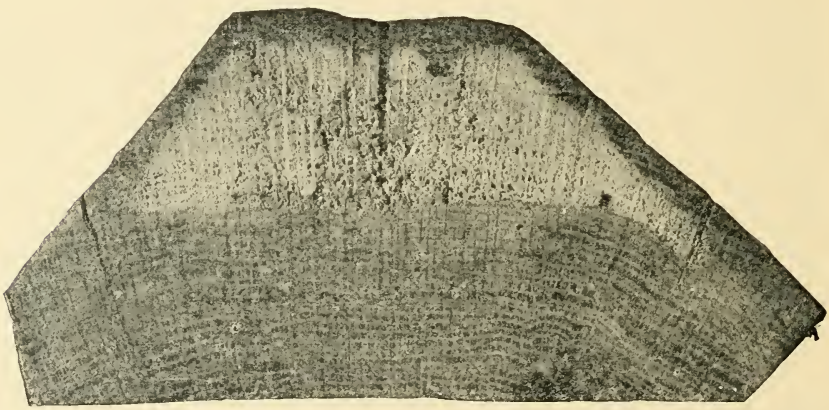

FIG. 11.—Cross section of an oak railroad tie rotted by one of the sap-rot fungi. Note the season crack through which the fungus obtained entrance to the interior.

of wood may appear perfectly sound on the outside and still may be wholly decayed in the inner part. In figure 11 a striking example of this is shown. This figure shows a section taken from a piece of "bottom" red oak cut in May, 1904. The timber was piled in the open, and the section here shown was taken in 1906. It will be noted that the outer quarter of an inch of wood appears perfectly sound and that immediately inside this sound layer the wood has been completely decayed. There was absolutely no external sign on this timber which would indicate that it was not sound throughout. Instances of this kind are numerous and they naturally give rise to much apprehension on the part of the purchaser of timber, because it is not practicable to cut into timbers for the purpose of determining whether they are sound on the inside.

The explanation for this form of sap decay is briefly as follows: When the stick of wood (fig. 11) was cut it was perfectly green and full of water. It was piled so that it was exposed on all sides to the wind and sun. As a result of this exposure the outer layers of the wood fiber dried very rapidly, and the amount of water left in the outer layers was insufficient for the development of the wood-destroying fungus. As a result of the drying, small season checks formed on the outside, one of which will be noticed in the middle at the top of the photograph. The season check penetrated into the interior for an inch or two; then some of the spores of the fungus lodged in it and there was still sufficient moisture to enable the spore to germinate and grow. The fungus then rapidly spread through the wet sapwood near the bottom of the season check, bringing about the decay shown in the figure. This decay would have gone on until all of the sapwood was destroyed, and fruiting bodies would then have formed on the outside in one of the season checks.

A very familiar instance of this kind of internal decay can be found in any forest where the stumps of trees are examined a year or more after the trees have been felled. The cut surface of the stump will appear season checked, but otherwise sound. When bored into, however, the wood within about a half inch of the upper surface of the stump will usually be found completely decayed. The realization that sap-rot in timber is due almost wholly to the action of fungi the spores of which enter through season checks and develop in the sapwood when it is not allowed to dry out is one of the most important practical considerations in connection with the entire study of the diseases of woods.

SUSCEPTIBILITY TO DECAY.

The same species of wood will show differing tendencies toward decay, according to the localities in which the trees are grown. This is well illustrated by the difference in lasting power which is found in so-called "hill" and "bottom" red oak (*Quercus rubra* L.). Hill red oak grows very much more slowly than bottom red oak, forming a denser grained, heavier wood, which is less permeable by water. In figure 10 the results of an extensive experiment comparing hill and bottom red oak are shown. This figure shows the results of exposing some 2,400 pieces of hill and bottom red oak. One hundred pieces were cut every month, beginning in January, 1903, and continuing until December, 1904. Two tracts of land were selected—one on which the hill variety grew and the other some 50 miles away, on which a dense bottom red-oak stand was growing. All of the timbers were piled in a similar manner and were left for observation.

With the exception of several months' cut of the hill red oak, the programme was carried out for two years. The numbers at the left of the figure indicate the percentage of timbers upon which masses of wood-destroying fungi were growing and which were obviously decayed to a greater or less extent. No account could be taken of internal decay, as just referred to, where no sporophores were formed, because it was not possible to cut into the pieces.

Figure 10 shows one thing very strikingly, namely, the greater percentage of decay in bottom red oak than in hill red oak. This is especially noticeable for certain months—for instance, August and September, 1903, where in the case of the bottom red oak 28 and 42 per cent, respectively, were decayed, while with the hill red oak but 6 per cent were decayed. When exposed for but a brief period of time, the difference between the two timbers is not so striking, as is shown by the last months included in figure 10. This is readily explained by the fact that the decay had not advanced far enough for the formation of fruiting bodies of the fungus, except in those timbers where infection first took place. If the timbers cut in June, July, August, etc., had been left as long as those cut the year before, the difference would probably have been equally as striking as during 1903.

PREVENTIVE METHODS.

The prevention of decay due to one or the other of the fungi just described may be brought about in one of two ways: First, by placing the wood under such conditions that the wood-destroying fungi can not develop; second, by treating the wood with chemical preservatives which act as poisons for the wood-rotting fungi. Both of these methods are successful, and it is usually necessary to employ both in conjunction.

One of the most important preliminary steps in the handling of timber after it is cut from the log is to dry it out as rapidly as possible. The drying process should aim to remove the water as equably as possible from all parts of the stick, so that excessive checking may not result. Where the drying does not take place uniformly, infection by sap-rotting fungi occurs, as has been most strikingly shown (fig. 11). All wood should be kept from contact with the soil for a certain period after it is cut from the tree, and only after it has been thoroughly dried should it be thus exposed.

Where wood is to be chemically treated, especially those species which are very susceptible to sap-rotting fungi, like the red oak (*Quercus rubra* L.), beech (*Fagus atropunicea* (Marsh.) Sudworth), red gum (*Liquidambar styraciflua* L.), etc., the greatest care should be used to pile the wood so that no two pieces shall touch more than is absolutely necessary. Timbers should, furthermore, not be piled

for too long a period, because, so far as known up to this time, the only safe method for avoiding the chance of getting sap-rotted pieces, such as shown in figure 11, is to chemically treat the wood before the fungus has had an opportunity of getting a foothold.

Where large timbers are used, it is always well to lessen the chances of internal decay, or so-called dry-rot, by building composite timbers. Some recent striking instances were noted in a large building where 12 by 12 inch oak timbers were used for posts and beams. One of the wood-destroying fungi had gained entrance through the lower ends of some of these vertical posts, had grown up through them without any signs on the outside, and had infected the horizontal beams. The decay had proceeded from the cellar to the tenth story of the large factory building. The discovery of the decayed condition was made when a hole was bored into one of the timbers for the purpose of inserting a screw; the timbers were then removed, and it was found that they had entirely decayed with the exception of a shell of about an inch in thickness on the outside. In reconstructing this building oak timbers were used, but instead of using 12 by 12 inch pieces for posts they were made of four 3 by 12 inch pieces bolted together. The chances for internal decay of such posts will be much lessened. The most efficient method for preventing the decay of timber consists in chemical treatment. References to this subject will be found in the bibliography appended hereto (12, 13, 14, 15, 28, 29, 64, 81, 85, 86, 90, 91, 103, 108).

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PLATES.

DESCRIPTION OF PLATES.

PLATE I. *Frontispiece.* A tree of aspen (*Populus tremuloides*) bearing several sporophores of *Fomes igniarius.* The tree is badly rotted within, and the fungus has formed its fruiting bodies at old knot holes left by the dying of small lateral branches. The tree is still alive, but is sure to die within a few years.

PLATE II. Effect of *Fomes igniarius* upon living trees. Fig. 1.—Cross section of the trunk of a tree of silver maple (*Acer saccharinum*) which bore but one fruiting body, this being the only external indication of disease. Note the black, narrow zones surrounding the completely decayed wood; also the place of entrance at the upper right-hand corner produced by the rotting of a dead lateral branch. Fig. 2.—Cross section of a living tree of aspen badly diseased with the white heart-rot. Note concentric, dark zones surrounding the diseased part.

PLATE III. Decay of living trees caused by wound fungi. Fig. 1.—Cross section of a living tree of beech (*Fagus atropunicea*) decayed by *Fomes igniarius.* This tree bore but a single fruiting body, this being the only external indication of disease. The decay extended about 4 feet both upward and downward from the sporophore. Fig. 2.—Cross section of the trunk of a living red oak (*Quercus rubra*) rotted by *Fomes everhartii.*

PLATE IV. *Polyporus sulphureus.* Fig. 1.—A large compound fruiting body of *Polyporus sulphureus,* such as is very often found. Fig. 2.—Cross section of the trunk of a living tree of post oak (*Quercus minor*) rotted by *Polyporus sulphureus.*

PLATE V. Piped-rot. Fig. 1.—Longitudinal section of the trunk of a living tree of black jack oak showing the piped-rot. Fig. 2.—A piece of chestnut wood diseased with the piped-rot.

PLATE VI. *Fomes nigricans.* Fig. 1.—Cross section of the trunk of a living tree of paper birch (*Betula papyrifera*) diseased by *Fomes nigricans.* Fig. 2.—The trunk of a paper birch (*Betula papyrifera*) showing an irregular aborted sporophore of *Fomes nigricans* growing at an old wound.

PLATE VII. *Hydnum erinaceus.* Fig. 1.—Cross section of the trunk of a living tree of white oak (*Quercus alba*) with the heartwood rotted by this fungus. Note below, at the left, two burrows of the oak borer through which this fungus probably entered. Fig. 2.—Fruiting body of *Hydnum erinaceus* growing in a hollow oak trunk.

PLATE VIII. *Fomes fomentarius.* Fig. 1.—Sporophores growing upon a dead tree of beech (*Fagus atropunicea*). Fig. 2.—Cross section of the trunk of a dead beech tree with the sapwood rotted by this fungus; the heartwood is practically sound.

PLATE IX. *Polyporus betulinus.* Fig. 1.—A dead trunk of yellow birch (*Betula lutea*) with a large sporophore of *Polyporus betulinus.* This fruiting body measured about 1 foot in diameter. Fig. 2.—Cross section of the trunk of a dead yellow birch tree with a fruiting body of *Polyporus betulinus.* The wood is entirely rotted.

PLATE X. *Daedalea quercina.* Fig. 1.—An oak railroad tie with fruiting bodies of *Daedalea quercina.* The tie is badly decayed within. Fig. 2.—A section of the above tie 2 feet from the end bearing the fruiting bodies of the fungus. It will be noted that in the lower part it is quite seriously affected.

FIG. 1.—CROSS SECTION OF THE TRUNK OF A LIVING SILVER MAPLE ROTTED BY FOMES IGNIARIUS.

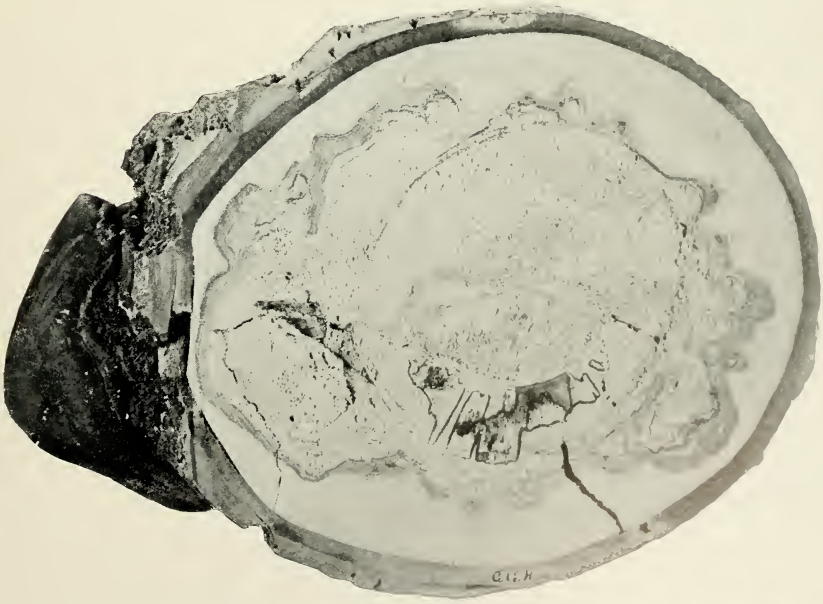

FIG. 2.—CROSS SECTION OF A LIVING ASPEN TREE ROTTED BY FOMES IGNIARIUS.

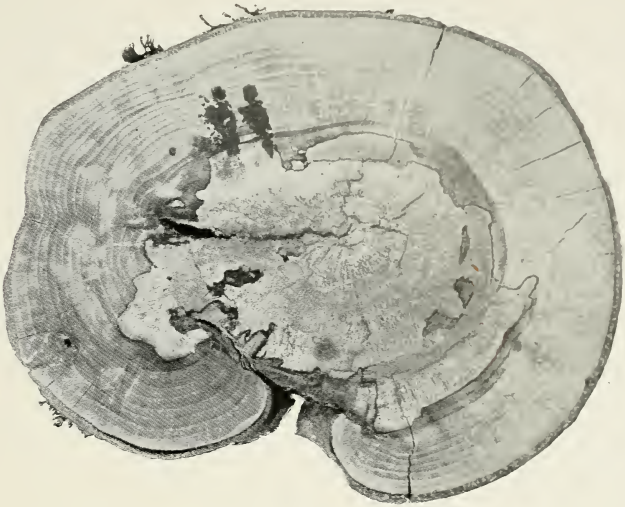

FIG. 1.—CROSS SECTION OF A LIVING BEECH TREE DISEASED BY FOMES IGNIARIUS.

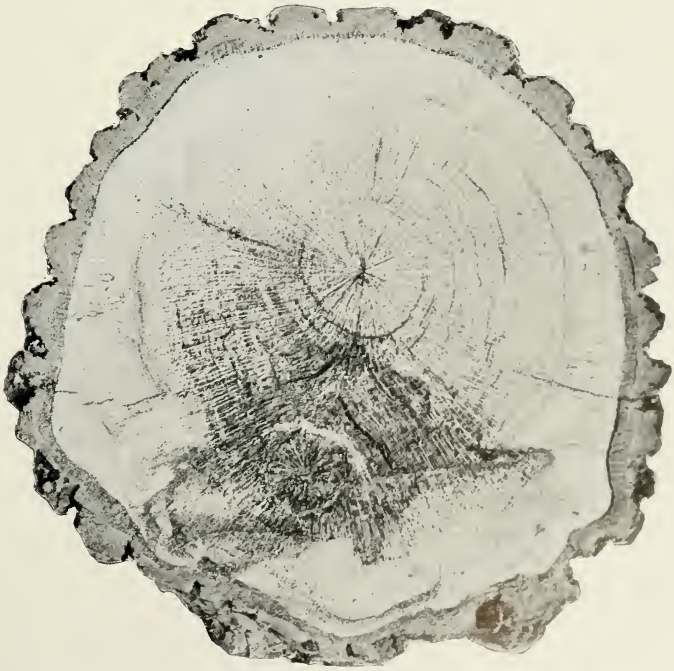

FIG. 2.—CROSS SECTION OF A LIVING RED OAK TREE ROTTED BY FOMES EVERHARTII.

FIG. 1.—FRUITING BODY OF POLYPORUS SULPHUREUS.

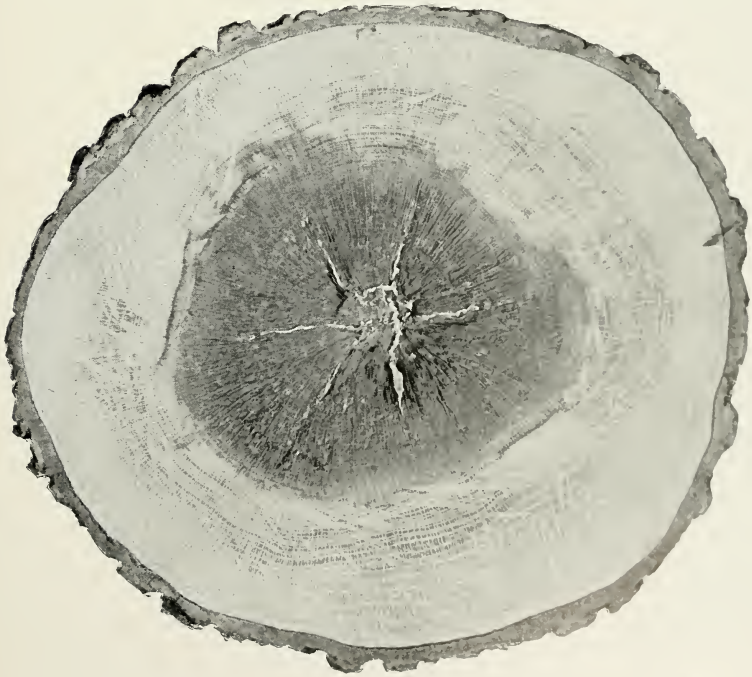

FIG. 2.—CROSS SECTION OF A LIVING POST OAK TREE ROTTED BY POLYPORUS SULPHUREUS.

FIG. 1.—PIPED-ROT OF OAK.

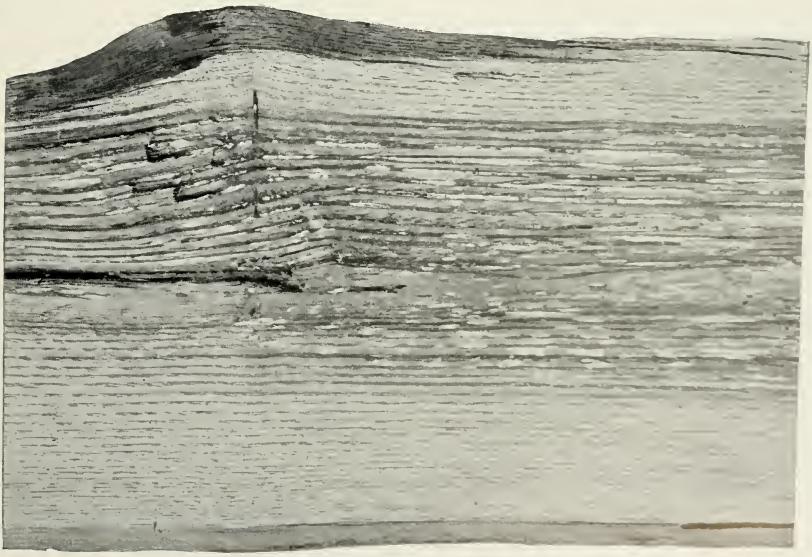

FIG. 2.—PIPED-ROT OF CHESTNUT.

Bul. 149, Bureau of Plant Industry, U. S. Dept. of Agriculture.

FIG. 1.—CROSS SECTION OF A PAPER BIRCH TREE ROTTED BY FOMES NIGRICANS.

FIG. 2.—AN ABORTIVE FRUITING BODY OF FOMES NIGRICANS UPON A LIVING TREE OF PAPER BIRCH.

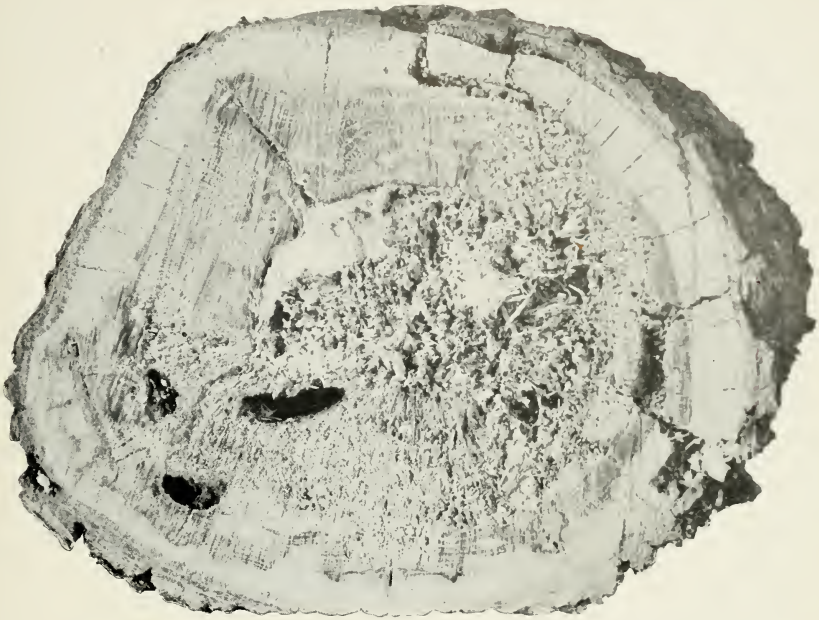

FIG. 1.—CROSS SECTION OF A LIVING WHITE OAK TREE DECAYED BY HYDNUM ERINACEUS.

FIG. 2.—FRUITING BODY OF HYDNUM ERINACEUS IN A HOLLOW LOG.

Bul. 149, Bureau of Plant Industry, U. S. Dept. of Agriculture.

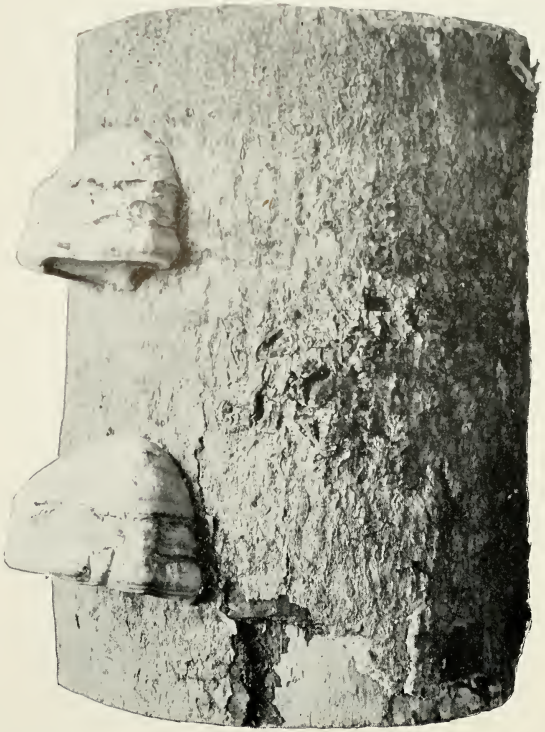

FIG. 1.—A DEAD BEECH TREE WITH SPOROPHORES OF FOMES FOMENTARIUS.

FIG. 2.—CROSS SECTION OF A DEAD BEECH TREE ROTTED BY FOMES FOMENTARIUS.

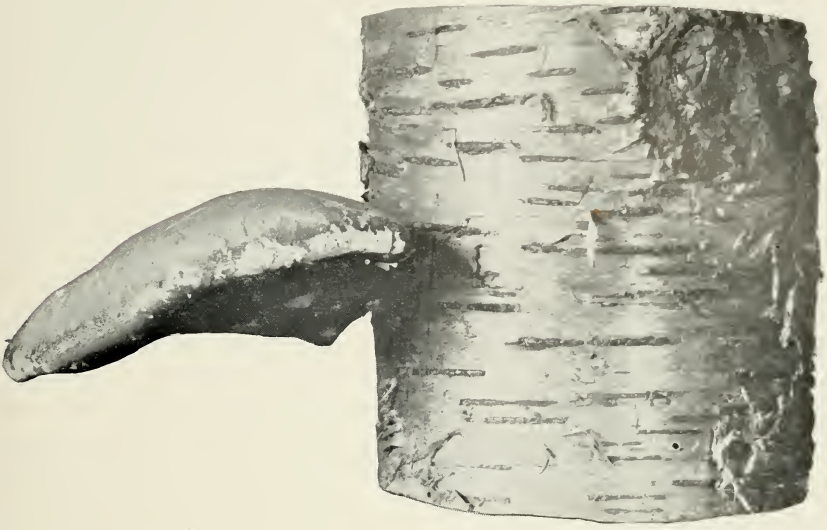

FIG. 1.—A DEAD YELLOW BIRCH TREE WITH FRUITING BODY OF POLYPORUS BETULINUS.

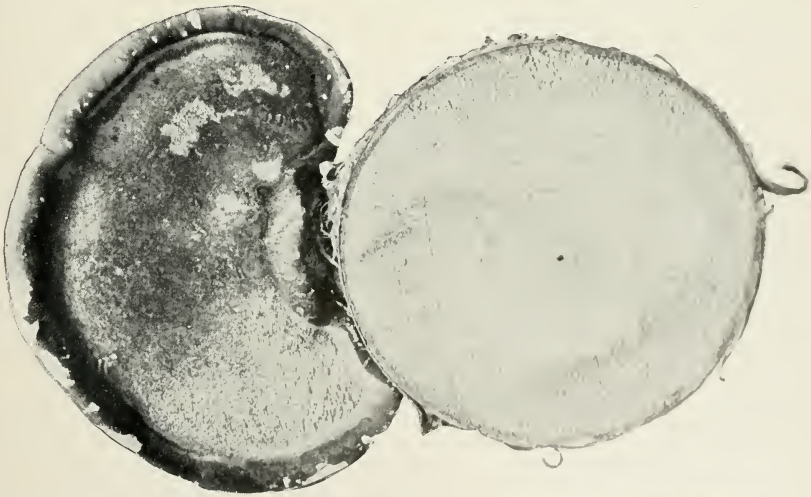

FIG. 2.—CROSS SECTION OF YELLOW BIRCH TREE ROTTED BY POLYPORUS BETULINUS.

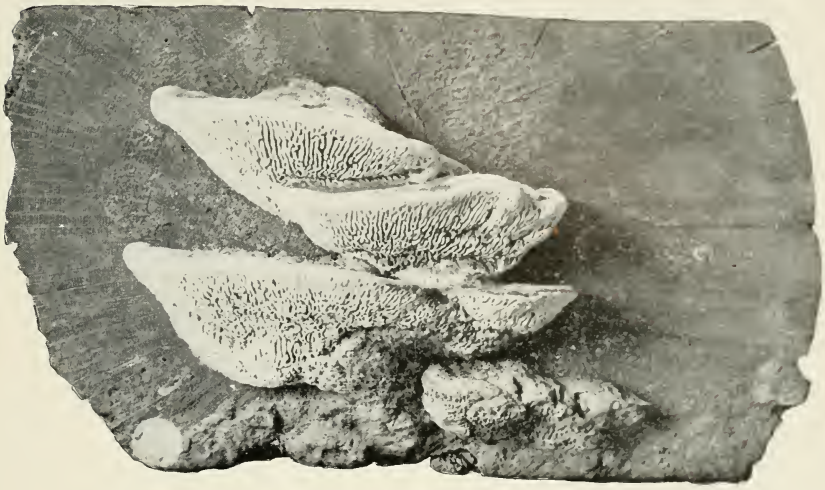

FIG. 1.—AN OAK RAILROAD TIE ROTTED BY DAEDALEA QUERCINA.

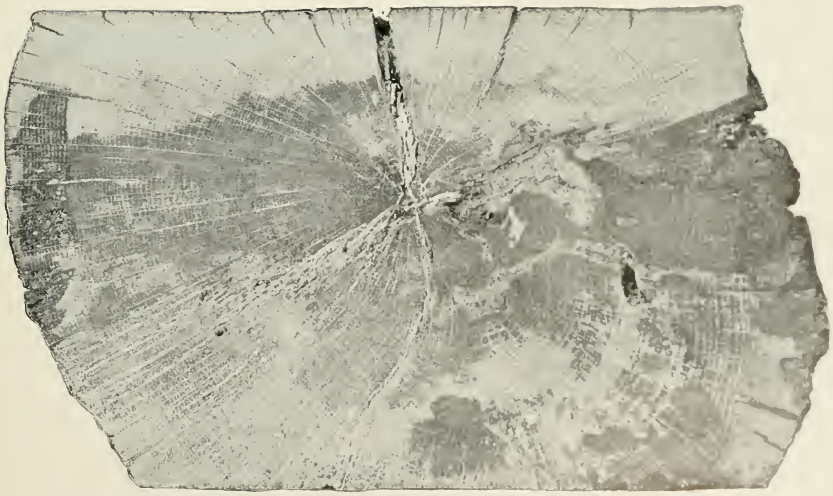

FIG. 2.—CROSS SECTION OF THE TIE SHOWN IN FIGURE 1, TWO FEET FROM THE FRUITING BODY.

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